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AIR FORCE CONCEPTUAL WEAPON SYSTEM OPTIMIZATION MODEL: PROOF OF CONCEPT STUDY

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13. ABSTRACT *(Maximum 200 words)*

The Air Force must be able to estimate the manpower, personnel, and training (MPT) resources required by the new or modified weapon systems proposed during the Concept Exploration phase of the acquisition process. A proof of concept study was conducted to determine whether data can be obtained to support the system of models proposed for making the estimates and whether the estimates will provide a sound basis for comparing the MPT life-cycle costs of the proposed weapon systems. The study concentrated on one Air Force Specialty while comparing two alternative support concepts for the Advanced Tactical Fighter. The study used the Logistics Composite Model to estimate the manning requirements for the two alternatives. The study explored a methodology for gathering and analyzing data on training requirements and costs. The study modified the Army Manpower Cost System to estimate and compare the life-cycle costs of the two alternatives. Several appendices detail the analyses conducted to support the study. The study found that data exist or can be collected to support the system models, although some work remains to firm up the collection methodology. The study also found that the conceptual framework for the proposed system of models provides a sound basis for comparing proposed weapon systems.

14. SUBJECT TERMS

Army Manpower Cost System, Life-cycle cost, Logistics Composite Model, Manpower cost, Personnel cost, Training cost, Weapon system acquisition

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PREFACE

This paper describes work done under USAF Contract No. F49650-88-D5001, Delivery Order 5032, Evaluate MPT Resource Requirements During Concept Trade Studies. The work was performed under AL/HRM Work Unit 77191927 by Systems Research and Applications Corporation. The objective of the effort was to conduct a proof of concept study for a system of models proposed to estimate the life-cycle cost of manpower, personnel, and training resources of weapon systems proposed during Concept Exploration.

This paper presents:

- A description of the analyses conducted to estimate manpower and training life-cycle costs;
- A comparison of the life-cycle costs of the two alternatives proposed in the proof of concept study; and
- An evaluation of the viability of the system of models planned for development.

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1. INTRODUCTION AND BACKGROUND

1.1. Goal of the SYSMOD Program

This paper describes the activities and findings of the second task of the SYSMOD (weapon system optimization model) research program being conducted by the Manpower and Personnel Division of the Human Resources Directorate of the Armstrong Laboratory (AL/HRM). The goal of the SYSMOD program is to develop a set of analysis models that will allow decision makers to consider the manpower, personnel, and training (MPT) resource availability and requirements of proposed weapon systems when choosing among alternatives during the very early phases of the Weapon System Acquisition Process (WSAP). SYSMOD concentrates on the Pre-Concept and Concept Exploration phases of the WSAP whereas a second AL/HRM research thrust, called the MPT Decision Support System, emphasizes the later phases beginning with Demonstration and Validation.

The initial version of SYSMOD concentrates on aircraft systems but it will consider other systems as well in the future. The scope of SYSMOD is currently limited to enlisted maintainers and support personnel. In practice, SYSMOD concentrates on enlisted maintainers and direct support personnel on the flight line and at the intermediate level (also referred to as shop or base level) of maintenance. Base operating support and depot maintenance personnel will be modeled later. The MPT resources modeled include number of positions by Air Force Specialty (AFS) and grade or skill level, and training requirements for people filling those positions.

In Pre-Concept, SYSMOD estimates the ability of the expected force structure to provide the MPT resources to maintain a new or modified system. In Concept Exploration, SYSMOD models the maintenance of the proposed systems to determine the maintenance hardware and MPT resources required to provide the planned system availability, where system availability is a measure such as percent time ready to fly or number of sorties per day the system can fly. Since MPT resources can be traded off with hardware resources (number of spares and support equipment), the relative costs of both are estimated. Thus SYSMOD estimates the life-cycle costs (LCCs) of both MPT and hardware resources. Ideally, SYSMOD assists the analyst in determining for each proposed system the combination of MPT and hardware resources that achieves the required system availability at a minimum LCC. These results can then be used in

tradeoff studies to determine which proposed systems should be advanced to Demonstration and Validation.

The study conducted in the first SYSMOD task proposed a conceptual framework for SYSMOD and produced a first version of a research and development (R&D) plan (Rue, 1991). The conceptual framework is divided into two parts: one for analysis models addressing MPT resource availability issues in the Pre-Concept phase of the acquisition process and a second for analysis models addressing MPT resource requirement issues in the Concept Exploration phase.

1.2. Goals of This Task

Because the development of SYSMOD for Concept Exploration offers both the bigger challenge and the greater reward, the current effort focused on a proof of concept study for SYSMOD in Concept Exploration. The goals of this second SYSMOD effort were to determine:

1. whether the data exist to support the proposed system of models and
2. whether the conceptual framework provides a sound basis for estimating the MPT resource requirements and LCCs of alternatives proposed during Concept Exploration.

In the proof of concept study, existing models designed for studies conducted later in the acquisition process were used to provide a first definition of data requirements for the framework. Existing data were examined to determine whether they satisfied the requirements imposed. Problems identified during the proof of concept study provided insight into the soundness of the conceptual framework and helped to refine the R&D plan proposed in the first study.

1.3. Overview of SYSMOD Conceptual Framework for Concept Exploration

Concept Exploration is a period when a number of weapon systems are proposed and evaluated in trade studies for their capacity to counter the threat that initiated the WSAP. SYSMOD should be used in these studies to compare the MPT resources required by the proposed weapon systems. Thus SYSMOD allows MPT factors to influence the design of the weapon system by including MPT resource constraints and LCCs in the trade studies. Ideally, SYSMOD should also be flexible enough to handle new data that become available in the later

phases of the WSAP so the analyst has a consistent set of data bases and tools to produce updated MPT resource estimates.

Since SYSMOD will be used to estimate the LCCs of the maintenance hardware and MPT resources required for each weapon system proposed during Concept Exploration, it cannot require elaborate detail or long periods of model preparation or analysis. In fact, detailed data are usually not available for proposed weapon systems. SYSMOD could be able to model both peacetime and wartime levels of performance. The level of performance is specified in terms of flying hours per aircraft per day or sorties per day (where sortie lengths are known or can be estimated). Thus the maintenance capacity will be designed to ensure aircraft are available for the required flying hours or sorties per day; or conversely, that aircraft are down no more than the remaining hours per day.

SYSMOD will be used to estimate the MPT LCCs of each proposed aircraft so they can be compared. For each aircraft, the user must input a description of the hardware that comprises the aircraft and the proposed support concept. Figure 1 displays a list, based on MIL-STD-780F, of the two-digit work unit code (WUC) categories used to represent the <u>systems</u> that comprise an aircraft. SYSMOD models an aircraft using the three-digit WUC categories, called <u>sets</u>.[1] A new aircraft is represented as a hybrid of systems and sets from existing aircraft. The system and set parameters required to model the maintenance of an aircraft such as mean time between failure (MTBF), mean time to repair (MTTR), and maintenance task crew size are drawn from the comparison system data base and modified by the user for any changes anticipated for the new system.[2] The user must describe the support concept for the proposed weapon system. The support concept description includes the levels of repair for systems and sets, the assignment of maintenance tasks to AFSs, and the shift structure (length of each shift and the number of airmen in each AFS assigned to each shift). The user must also describe the weapon system performance requirements in terms of number of aircraft simulated and required flying schedule so that SYSMOD can determine whether the maintenance resources being simulated are sufficient to provide the required aircraft availability rate.

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[1] For example, WUC 63000 represents the UHF Communications <u>System</u>, WUC 63A00 is the UHF Electronics <u>Set</u>, and WUC 63B00 is the Integrated Com-Nav Control <u>Set</u>.

[2] The comparison system for Concept Exploration studies may be simply the parent system.

WUC	Description
11	Airframe
12	Crew Station
13	Landing Gear
14	Flight Controls
23	Engine
24	Auxiliary Power Plant
41	Environmental Control System
42	Electric Power System
44	Lighting System
45	Hydraulic/Pneumatic Systems
46	Fuel System
47	Oxygen System
49	Miscellaneous Utilities
51	Flight Instruments
55	Malfunction Analysis Recorder
62	VHF Communications System
63	UHF Communications System
64	Interphone System
65	Identification Friend/Foe (IFF)
66	Emergency Radio System
71	Radio Navigation System
72	Radar Navigation System
74	Fire Control System
75	Weapon Delivery System
76	Penetration Aids and Electronic Countermeasures

Figure 1. Two-Digit Work Unit Codes

Figure 2 depicts the SYSMOD architecture proposed in the first study (Rue, 1991). The major components of SYSMOD are a comparison systems data base from which a baseline comparison system (BCS) can be formed, a simulation model of the maintenance of the aircraft, an LCC model for MPT resources and selected hardware resources, and tradeoff models to investigate alternative combinations of maintenance hardware and MPT resources.

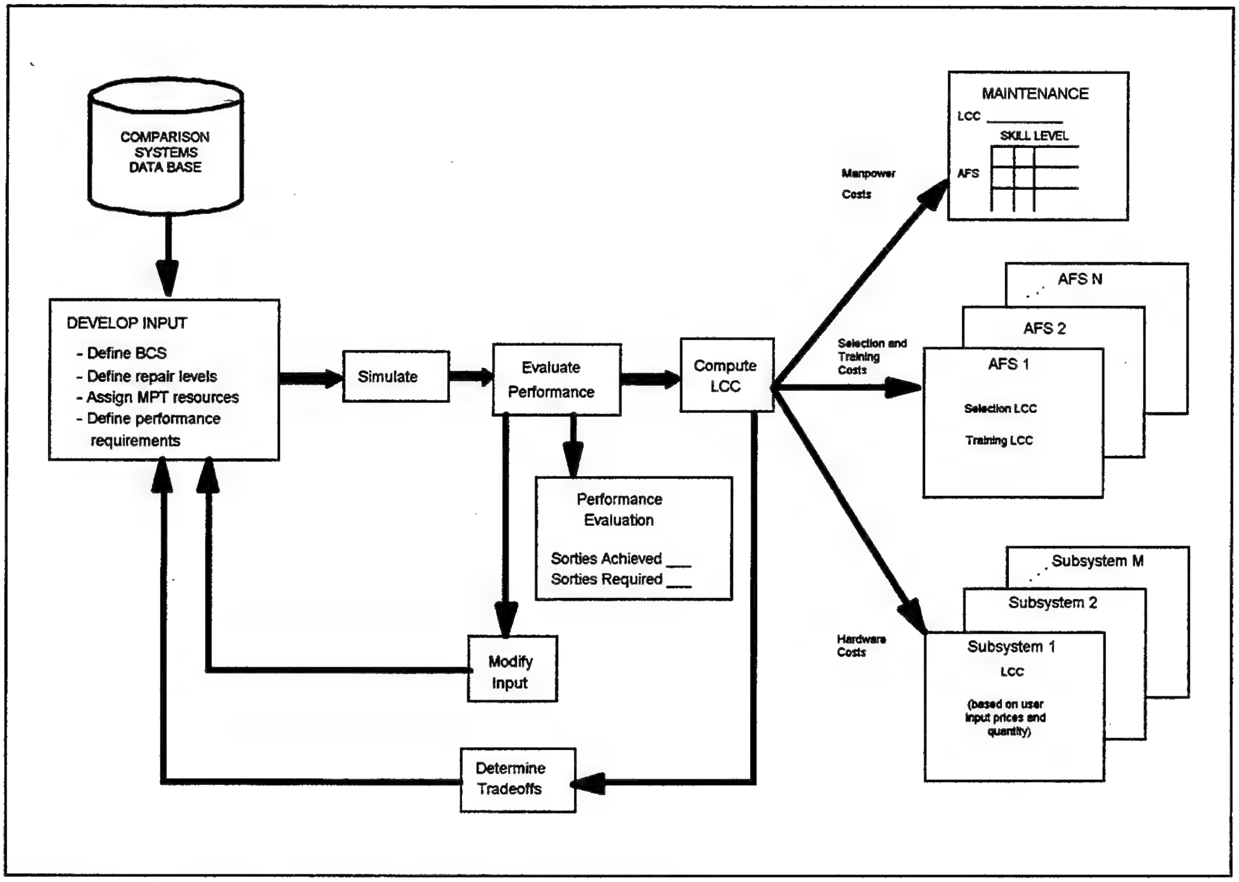

Figure 2. SYSMOD During Concept Exploration

The comparison systems data base allows the SYSMOD user to represent the maintenance characteristics of the systems and sets on the proposed aircraft by selecting the most similar current system from the data base and modifying data describing its maintenance to bring them in line with the proposed aircraft.

The simulation generates maintenance demand as a function of the flying schedule and the maintenance parameters of the new aircraft. The simulation attempts to satisfy the maintenance demand using the maintenance resources provided through the parameters of the support concept such as the assignment of tasks to AFSs and the shift structure. The simulation "plays out" the flying and maintaining of aircraft for an input period of time and reports the results. If the aircraft do not meet the flying schedule, the user should change the parameters of the support concept in order to meet the schedule. This may be an iterative process.

Once the simulation indicates that the new aircraft can meet the performance requirements (represented by the flying schedule), SYSMOD estimates the LCCs of maintaining the new

aircraft. The LCC model computes costs of manpower positions at both the flightline and intermediate levels of maintenance and computes the cost of selecting and training people to fill those positions.[3] The LCC model also computes costs of selected hardware resources provided for maintenance including support equipment and spares.

The tradeoff component of SYSMOD can be viewed as a collection of models that evaluate various combinations of maintenance resources searching for one that meets system performance requirements at the lowest LCC. Once the tradeoff models identify resource trades, the simulation model can be updated to reflect the changes and be rerun to reevaluate system performance (sortie rate or flying hours) and LCC. The tradeoff process continues until the user is satisfied the LCC of the maintenance resources required by the system cannot be reduced further.

SYSMOD produces measures of maintenance activity from the simulation including utilization rate of each AFS, down time for aircraft, and numbers of maintenance actions. The achieved sortie rate will also be output and compared with the required rate. Several categories of LCCs will be estimated including manpower costs by AFS and skill level or grade, selection and training costs by AFS, and costs of spares and support equipment involved in the MPT cost comparisons.

1.4. Overview of the Proof of Concept Study

The system of data bases and models described above was the subject of the proof of concept study. Because the main goals of the proof of concept study were to check the availability of data and the viability of the conceptual framework for SYSMOD in Concept Exploration, the study concentrated on MPT issues and not hardware issues. Thus the differences in the alternatives studied were primarily in the MPT resources they required causing the study to concentrate on MPT resource data and models. Several other factors helped define the specific issues addressed. To ensure that data from the Concept Exploration phase still existed, the study focused on an aircraft still in the acquisition process. In order to attract broader interest in the study than from just those interested in SYSMOD, the differences between the alternatives studied hinged on a topic of current concern to the Air Force. To limit the data gathering and

[3] The LCC model can also compute the cost of additional base operating support personnel needed as a result of maintenance manpower required for the new aircraft.

analysis effort, the study concentrated on a single flightline maintenance AFS and the systems and sets the AFS maintains.

The aircraft studied was the Advanced Tactical Fighter or ATF. The study focused on the ATF's Integrated Communications-Navigation-Identification Avionics (ICNIA) systems and the AFS that will maintain them on the flightline, hereafter referred to as Air Force Specialty Code (AFSC) 452XXC (ATF ICNIA Systems).[4] The differences between the two alternatives studied emanated from a difference in support concept. In the first alternative, the ATF squadrons were assigned to bases as independent units with their own maintenance squadrons providing flightline maintenance of the aircraft. In the second alternative, the ATF squadrons were assigned to composite units at bases with F-15 aircraft. The AFSC that conducts flightline maintenance on similar systems for the F-15 is 452X1C (F-15 Communication, Navigation, and Penetration Aids (Comm/Nav/Pen Aids) Systems).[5] In the second alternative, flightline maintenance of the ATF was provided by a composite maintenance squadron with some maintainers primarily assigned to the ATF and others primarily assigned to the F-15. However, maintainers in the composite units were cross trained to the 5-level in some maintenance tasks for the other aircraft.[6] Because the Air Force is currently forming composite units at several bases, the results of this study should also be of interest to analysts who are studying the implementation of these units.

In the first alternative, the Logistics Composite Model (LCOM) was used to simulate the maintenance for a squadron of 24 ATF aircraft to estimate the number of flightline maintainers needed for the ICNIA systems. The same model also simulated maintenance for a squadron of 24 F-15 aircraft to estimate the flightline maintenance manpower needed. Although both aircraft were run in the same model, the model treated the maintenance of the aircraft independently. ATF resources could only be used on the ATF, and F-15 resources could only be used on the F-15.

In the second alternative, both squadrons of aircraft were again represented in the same LCOM run. For this alternative, the study took advantage of an LCOM capability that allows the

[4] The systems in ICNIA include WUCs 62-66, 71, 72, and 74.

[5] Systems included in Comm/Nav/Pen Aids include WUCs 63, 65, 71, and 76.

[6] Because they are only qualified at the 5-level in some of the tasks, the cross trainees were not granted a 5-level in the secondary AFS.

user to identify an alternate or secondary resource for performing maintenance when the primary resource is unavailable. In the second alternative, a number of ATF ICNIA flightline maintenance tasks had F-15 maintainers identified as a secondary resource for performing the tasks. Similarly, a number of F-15 Comm/Nav/Pen Aids flightline maintenance tasks had ATF maintainers identified as a secondary resource for accomplishing the tasks. Members of the secondary AFS were assumed to take longer to perform tasks on their secondary aircraft than airmen from the primary AFS.

Assuming the ATF and F-15 aircraft could meet their flying schedules in both alternatives, the choice between the two rested on a comparison of their LCCs. The first alternative provided a baseline for LCCs. In the second, savings from the baseline might result from a reduction in required manpower due to the availability of a secondary resource. Also, costs above the baseline might result from cross training both ATF and F-15 maintainers for maintenance tasks on the other aircraft. The net effect of the savings and extra costs determined whether the second alternative was less expensive than the first. The study assumed that the Air Force would form one unit of F-15 and ATF squadrons per year for nine years, then keep those nine units until year 21 when it would reduce the number of units by one to eight. The reduction of one unit per year was assumed to continue until year 28 when the remaining two units would be deactivated.

The next section of the report describes the data gathered and the analyses conducted to compare the two alternatives. The section also details problems encountered with the data and in conducting the analyses.

2. DATA DEVELOPMENT

2.1. Scope

The proof of concept study was aimed at the primary processes required in SYSMOD: developing input data based on a BCS data base, simulating the maintenance of the aircraft, evaluating performance, and estimating LCCs. It did not exercise two of the proposed components of SYSMOD as portrayed in Figure 2. First, the study did not conduct any tradeoff studies aimed at reducing the LCC of each of the alternatives. Tradeoff studies might have examined the interaction of the MTBF or MTTR of the systems modeled with the MPT resources required for maintenance. However, maintenance parameters of the hardware were considered fixed for the study. Tradeoff studies might also have considered the interaction among MPT resources as a result of a different assignment of tasks to AFSs or of using new selection criteria for entry to an AFS.[7] The second component of SYSMOD that was not exercised in this study was the estimation of hardware LCCs. Because hardware resources were fixed for the study, hardware costs were not needed to compare the two alternatives.

WUC	Description
62000	VHF Communications System
62100	VHF Radio Set (AN/ARC182)
62X00	Associated VHF Equipment Set
63000	UHF Communications System
63200	UHF Radio Set (AN/ARC159)
63500	Digital Data Communications Set
63Y00	Associated UHF Equipment Set
64000	Interphone System
64X00	Associated Interphone Equipment Set
65000	Identification Friend or Foe System
65300	Transponder Set (AN/APX100)
65Y00	Associated IFF Equipment Set
66000	Emergency Radio Systems
66100	Radio Beacon Set
71000	Radio Navigation System
71300	Tactical Air Navigation (TACAN) Set
71D00	Receiving Decoding Set
71Y00	Associated Radio Navigation Equipment Set
72000	Radar Navigation System
72200	Electronic Altimeter
72900	Radar Beacon Set
72R00	Radar Navigation Related Equipment
72Y00	Radar Navigation Associated Equipment
74000	Weapons Control Systems

Figure 3. BCS for ATF

[7] The two alternatives studied are essentially task assignment alternatives where the AFSs considered are from two different aircraft.

2.2. Input

2.2.1. BCS and LCOM Data

BCS data for the ATF were taken from sources developed in the mid-1980's by AL/HRG in conjunction with their development of MPT analysis methodologies and software under the Small Unit Maintenance Manpower Analyses (SUMMA) project. Data remaining from that effort include LCOM data required to model three levels of maintenance for the ICNIA systems, although the data only portray depot maintenance as delays for repair of equipment that is not repairable at the intermediate level (Not Repairable This Station (NRTS)). Figure 3 lists the systems and sets in the BCS for ATF ICNIA systems; all are from the Navy's F-18. Appendix A lists the maintenance action code for each maintenance task performed on ATF ICNIA systems, crew size required for the task, and the expected task performance time, all of which were extracted from the LCOM data set.

LCOM data for the F-15 were taken from an Air Combat Command (ACC) LCOM model used by AL/HRG in the late 1980s. The F-15 data also model three levels of maintenance and limit the representation of depot actions to delays for hardware that is NRTS. Figure 4 lists the Comm/Nav/Pen Aids systems and sets in the F-15 LCOM model. Appendix B also displays the maintenance action code for each maintenance task performed on F-15 Comm/Nav/Pen Aids systems, crew size needed, and expected task performance time as given in the LCOM data set.

WUC	Description
63000	UHF Communications System
63A00	UHF Communications Set
63B00	Integrated Comm/Nav/IFF Set
65000	Identification Friend or Foe System
65A00	Transponder Set
65B00	IFF Interrogator Set
71000	Radio Navigation System
71C00	Instrument Landing Set (ILS)
71D00	Tactical Air Navigation (TACAN) Set
71F00	Attitude Heading Reference Set (AHRS)
71Z00	AN/ARN-118 TACAN Instl
76000	Tactical Electronic Warfare System (TEWS)
76A00	Countermeasures Receiving Set (AN/ALR-56)
76C00	Interference Blanker
76G00	Countermeasures Set (AN/ALQ-128)
76H00	Countermeasures Set (AN/ALQ-135V)

Figure 4. BCS for F-15

2.2.2. Support Concept

As indicated in the discussion above, the support concept for the ATF and the F-15 included three levels of maintenance for both of the alternatives although depot

manpower was not modeled. The availability of spares and support equipment were also the same for both alternatives. The only aspect of the support concept that varied was under the second alternative, the composite unit alternative, where a secondary AFS was available for performing some maintenance actions. The rest of this section describes the process used to modify the BCS LCOM data to model the availability of a secondary AFS.

Choosing Tasks for Performance by Secondary AFS: The first step in preparing LCOM data was to select tasks that members of the secondary AFS would perform and for which they should be cross trained. The study assumed that airmen in the composite unit maintenance organization would be primarily assigned to one aircraft, but that they could be cross utilized on the other aircraft depending on relative workload and mission priority for the two types of aircraft. Although some people interviewed during the study felt that the Air Force would only cross train the entire set of tasks for an AFS, as is done during retraining from one AFS to another, the study took a less restrictive view of the choice of tasks and considered cross training subsets of an AFS's tasks. The process of considering task subsets for cross training forced the study to investigate whether data exist to model training requirements and costs at more detailed levels than the total of all tasks assigned to an AFS.

Three main factors determined the selection of tasks to be cross trained. First, cross training costs were to be minimized. Thus, if two groups of tasks produced the same manpower savings, the one with the smaller training cost should be chosen to minimize overall costs. In general, choosing tasks that require similar sets of knowledge, skills, and abilities (KSAs) would tend to limit training costs.

The second factor affecting task selection was safety. Because the Air Force is a conservative, safety conscious organization, the study assumed that the Air Force would authorize members of the primary AFS only to certify completion of maintenance tasks. As a result, the study required one person from the primary AFS on each crew and did not consider assigning one-person tasks to the secondary AFS.

A third factor affecting cross training task selection was the reduction of manning requirements for the primary AFS. The flexibility afforded by having a secondary AFS should produce manpower economies for the primary AFS 1) by permitting a limited number of primary AFS personnel, in conjunction with secondary AFS personnel, to perform more primary aircraft maintenance, 2) by allowing primary AFS personnel to concentrate on more specialized tasks,

thus completing the same total maintenance more efficiently and so faster, and 3) through efficiencies as in 2), by allowing fewer people from the primary AFS to complete the total maintenance effort in the same time.

In light of the factors above, the first step in selecting tasks for cross training was to identify groups of tasks requiring similar KSAs in order to restrict the search to combinations with limited training costs. The study examined two methods for identifying these groups of tasks, the co-performance method and the WUC method.

The first method for grouping tasks is the co-performance method. Task co-performance is a measure of the tendency for tasks to be performed by the same people; it is reported as a percentage. Two tasks have high co-performance if most of the people who perform one task also perform the other. The basis for using this measure in the study was the assumption that the need for efficiency in the workplace causes supervisors to repeatedly assign airmen to tasks requiring a relatively narrow set of KSAs. As a result, the supervisor ensures the workload facing the organization is accomplished, and the airmen become proficient at the tasks and tend to specialize within their AFSs.

To examine co-performance, the study needed to correlate the LCOM tasks which are based on Maintenance Data Collection System (MDCS) data gathered for the maintenance and logistics communities with Occupational Survey (OS) data used by the training community and serving as the basis for co-performance analyses. Several recent reports describe research conducted by both AL/HRT and AL/HRM into streamlining or automating the process of mapping MDCS data to OS data (Wagner, 1986 and Metrica, 1991). This study's mapping procedure borrowed heavily from Metrica's findings, although it did not use Metrica's automated mapping procedure due to lack of data. Appendix C describes the process followed for mapping LCOM tasks to OS tasks and displays the results for the F-15.[8]

Co-performance measures were produced by applying Comprehensive Occupational Data Analysis Programs (CODAP) routines to OS data for tasks identified in the LCOM mapping, for members of AFS 452X1C with four years of service or less. The study assumed that supervisors will treat cross trainees as relatively inexperienced maintainers and will assign them to tasks

[8] Because the BCS for the ICNIA systems on the ATF was the Navy's F-18 and hence Air Force OS data did not exist, the study did not use the co-performance method for the ATF.

normally assigned to airmen with four years of service or less. Appendix D describes the study's process of using co-performance measures to cluster tasks into co-performance groups in order to identify groups of tasks as candidates for cross training.

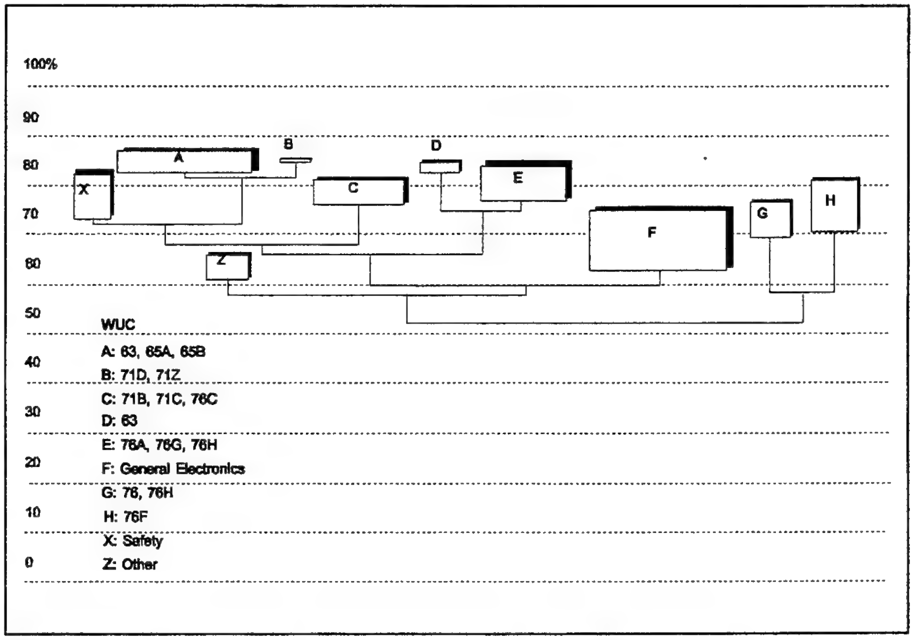

Figure 5. F-15 Tasks Aggregated by Co-Performance

Figure 5 summarizes the results of the clustering. In Figure 5 the height of each rectangle indicates the range of co-performance measures for tasks in the cluster and the width of the rectangle is proportional to the number of tasks in the cluster. The lines connecting rectangles indicate how the clusters combine to form larger groups. Most of the hands-on maintenance tasks were highly co-performed with one another so there were few prominent breaks between clusters of tasks. However, the clusters tended to contain all tasks associated with one or more three-digit WUCs. Figure 5 lists the WUCs that comprise each cluster. This result gave rise to the second approach, the WUC approach, to identifying sets of tasks for cross training.

The WUC approach to identifying tasks with similar KSAs forms a cluster of tasks for each three-digit WUC set. Thus maintenance tasks associated with a three-digit WUC form the smallest clusters of tasks. The hypothesis behind this approach is that limiting the types of equipment maintained yields a narrow range of KSAs for cross training. Because the approach does not use OS data, it can be applied to the ATF (F-18) as well as to the F-15. Larger clusters of tasks can be formed by grouping clusters within the same two-digit WUC system.

Both the co-performance method and the WUC method seek groups of tasks with a narrow range of KSAs and so should tend to identify similar groups of tasks. Since the co-

performance method is less restrictive, it may yield groups that are composed of three-digit WUC sets from different systems. For small clusters, it may even group on maintenance action (e.g. cluster troubleshooting tasks together). The co-performance method also tends to isolate difficult or complex tasks, tasks performed by only a few, specialized 5 or 7-levels, into small clusters. Tasks such as these were not considered for cross-training in this study because they would not be assigned to inexperienced maintainers.

On the basis of the above finding regarding complex tasks, the WUC approach was modified to identify and eliminate tasks requiring specialization. A recent study proposed a simple process for identifying these tasks when OS data are available (Driskill, 1987). The process identifies tasks requiring specialization by selecting those with a learning difficulty greater than one standard deviation above the mean, and with the percent members performing less than one standard deviation above the mean.[9] The study applied this additional process to the F-15 tasks but found that none were eliminated.[10]

Because the WUC method could be applied to both the ATF and the F-15, the study chose to start with the 3-digit WUC clusters of tasks resulting from that method. The second step in selecting tasks was to eliminate any one-person tasks from clusters. The study eliminated these tasks because of their potential for safety problems if they were performed by members of the secondary AFS acting alone.

The modified groups of tasks were ranked by their contribution to the expected workload for the primary AFS. The expected workload for a task was computed as the product of the number of sorties per day for the squadron, the per sortie probability of the task being required, the expected performance time of the task, and the number in the crew. The ranking for each set of tasks was determined by summing the expected

WUC	Expected Workload
62	10.53
65	5.21
71	3.37
72	3.27
66	0.75
74	0.73
63	0.32
64	0.05

Figure 6. Expected Workload for 72 ATF Sorties

[9] The tasks selected by this process are both difficult to learn and are performed by relatively few people.

[10] No isolated groups were identified by the co-performance method either.

workloads of the tasks in the three-digit WUC cluster.[11]

To limit later data gathering and analysis efforts, the study aggregated three-digit WUC clusters into two-digit WUC clusters. Figure 6 displays the rank ordering of two-digit WUC clusters for the ATF and Figure 7 displays the rank ordering for the F-15.

The third step was to choose the groups of tasks from the rank ordered lists to be cross trained. Even though WUC 76 (Tactical Electronic Warfare System) tasks were ranked at the top of the F-15 expected workload list, they were eliminated from consideration for cross training because the ATF had no similar group of tasks. Once the WUC 76 group was dropped, only the top two groups were chosen for each aircraft in this study in order to limit the analyses required for LCC estimation. Thus WUC 62 and 65 tasks were chosen for the ATF and WUC 65 and 63 tasks were chosen for the F-15.

WUC	Expected Workload
76	79.30
65	22.98
63	13.68
71	4.12

Figure 7. Expected Workload for 72 F-15 Sorties

Estimating Task Performance Times for the Secondary AFS: Once the study identified the groups of tasks chosen for cross training, it had to estimate the task performance times for maintenance crews that included people from both the primary and the secondary AFSs. Gathering empirical data to make these estimates would be difficult for both technical and cost reasons.[12] The study sought to use existing data to make the estimates. The most promising data came from studies done in the mid-1980s by AL/HRG as a part of their SUMMA research program. The SUMMA effort gathered task performance time data for the F-16 (Boyle, 1990) and for the F-18 (no report published).

[11] Appendices A and B list the rank ordered sets of tasks for each aircraft.

[12] Collecting empirical data for this study requires crews composed of both Air Force and Navy personnel to be cross trained and then timed on the chosen maintenance tasks.

Because the SUMMA data for the F-18 included many of the LCOM tasks associated with the ICNIA systems, the study examined the F-18 data first, looking for a simple approach to estimating performance times for mixed crews. The SUMMA effort interviewed maintainers of the F-18 to collect data on each task from each person that included the following:

- estimate of performance time for a crew composed of people from a secondary AFS
- estimate of difficulty for the task (5-point scale)
- estimate of electronic knowledge required (7-point scale)
- estimate of mechanical knowledge required (7-point scale)

The study examined these data looking for a simple method for estimating the performance time for a crew composed of people from the secondary AFS. The study assumed that airmen from the secondary AFS would not perform the tasks as frequently as airmen from the primary AFS; thus the study attempted to use secondary AFS SUMMA task times. Other AL/HRM research on productive capacity (Leighton, 1992) may also produce a method to estimate task performance times. The study then extended the method to estimate the performance time for a mixed crew.

The results of the examination of F-18 data were disappointing (see Appendix E). Only a handful of subjects were interviewed, and their responses were too varied to yield useful regression models for estimating times for secondary crews. The study then turned to the SUMMA data for the F-16.

The SUMMA data for the F-16 included estimates from 20 to 24 people for each of the 452X2C tasks studied and were more consistent than those for the F-18.[13] The study examined functions that estimated secondary AFS performance time as a function of primary AFS performance time, the SUMMA estimates of task difficulty and knowledge required, and OS estimates of task learning difficulty. The best regression model estimated secondary AFS performance time simply as a function of primary AFS performance time where secondary time was 1.24 times primary time. The study assumed that this function, based on F-16 data, applied to both the ATF (F-18) and the F-15. It applied the 1.24 factor to primary AFS times from LCOM data to estimate secondary times for tasks selected for cross training.

[13] At the time the SUMMA study was conducted the AFSC for F-16 Avionics was 326X8C.

The study found no data on which to base a method for combining the primary crew and secondary crew times into a mixed crew time. The study assumed that the mixed time was between the two estimates and calculated it as the average of the two times. Because the AFS crew time for the secondary crew was 1.24 times the primary AFS crew time, the mixed crew time was 1.12 times the primary crew time.[14] Note that all of the tasks selected for cross training were two-person tasks except for one three-person task. Input to the LCOM model identified mixed crews as the second choice for completing each cross-trained maintenance task. Options were set so LCOM first searched for an available primary crew before selecting a mixed crew to complete a task.

2.2.3. Operating Concept and Performance Requirements

The main effect of the operating concept on the study was in the generation of maintenance workload. Because only a few tasks were chosen for cross training, the availability of a secondary AFS would not have much of an effect on manpower requirements unless the workload for the AFS was large. Thus the operating concept was designed to call for an intense flying schedule that required three sorties per day for all 24 aircraft of each type, or 72 sorties per day for each squadron.[15]

The performance measures for the system were given in terms of achieved sorties per day versus required sorties. The study attempted to provide the maintenance units in the two alternatives with just enough people to keep manpower from becoming a limiting factor in meeting the required sortie rate, thus minimizing the manpower costs for each alternative.

[14] LCOM requires a probability distribution as input for task performance times. The LCOM models for the ATF and F-15 use normal and log-normal distributions. In the study, the mean of the distribution for the primary crew was multiplied by 1.12 to estimate the mean for the distribution for the mixed crew. The variance of the distribution for the mixed crew was unchanged from that for the primary crew.

[15] As shown in Section 3.1.2, the LCOM model for the F-15 could not achieve three sorties per day per aircraft even with unlimited manpower.

3. ESTIMATING MANPOWER AND TRAINING REQUIREMENTS

3.1. Manpower Requirements

The study used LCOM to simulate the maintenance of aircraft for both the independent and the composite maintenance alternatives. As mentioned in Section 2.2.1, existing LCOM models of the ATF and F-15 were used in the study. Note that the manpower requirements estimation model used in SYSMOD does not need to be as detailed as the LCOM models used in the study and should be designed to be much easier to run than the LCOM models were. However, the LCOM models were readily available and allowed the study to concentrate on the objectives of the task: investigating data availability and evaluating the soundness of the conceptual framework for SYSMOD.

3.1.1. Models of the Two Alternatives

LCOM is a Monte Carlo simulation model written in Simscript II.5 that represents the generation of aircraft sorties as events that are scheduled according to a user input mission plan. Both scheduled and unscheduled maintenance are modeled as task networks where the network branches taken depend on the outcomes of random draws. For instance, a troubleshooting task might be followed by a remove and replace task or by a minor repair task, depending on the random draw. The tasks in the networks for AFSs 452XXC (ATF ICNIA Systems) and 452X1C (F-15 Comm/Nav/Pen Aids) are listed in Appendices A and B. The model enters the networks whenever maintenance is scheduled or an aircraft system fails. Aircraft system failures occur according to probability distributions input by the user. Typically, these distributions are based on studies of actual failures over some period of aircraft operation or are estimates of distributions for systems yet to be built. When the model enters a maintenance network, it assigns a maintenance crew to the first task in the network and draws a random task time from the distribution for the task performance time. At the end of the task, LCOM releases the crew and proceeds to the next task according to the network branches and any random draws needed. If LCOM cannot find a maintenance crew, it places the task in a queue (backorders the task) until a crew is available. When the model reaches the point in the network where the aircraft is repaired, it releases the aircraft to fly although it may continue through the network. For instance, the network may continue to represent the repair process for a defective line replaceable unit (LRU)

that is sent to the intermediate maintenance level for repair. Because LCOM results depend on the outcome of a number of random draws, LCOM models are usually run several times to develop distributions of results.

In the independent maintenance alternative, LCOM searched only the primary AFS for a maintenance crew. Those airmen were trained for just their primary aircraft and could not be used on the secondary aircraft. In the composite unit alternative, LCOM searched for a work crew in the primary AFS first. But for those tasks that were cross trained, LCOM expanded the search if a crew from the primary AFS was not available. The expanded search was for a crew with at least one member of the primary AFS with other members coming from the secondary AFS. If a mixed crew from the primary and secondary AFSs were used, LCOM chose the task performance time from a distribution with a mean 1.12 times the mean a crew wholly from the primary AFS (See Section 2.2.2). Thus, compared to runs of the independent alternative with the same shift manning, fewer cross trained tasks should be backordered in the composite unit alternative because crews were more available, but the average performance times should be somewhat longer depending on the relative use of primary and mixed crews. The added flexibility of the composite unit alternative could lead to a savings in manpower spaces if the demand for cross trained tasks were great enough and airmen were available from the secondary AFS.

3.1.2. Results of LCOM Runs

The first LCOM runs were made with the independent alternative (no resource substitution) with unconstrained manpower resources. Each squadron of 24 aircraft had 200 airmen for each of two 12 hour shifts per day. The resulting number of sorties flown set an upper bound on sorties achievable when the model was run with more realistic manpower resources. The results of one unconstrained run for 30 days are shown in Table 1. In the unconstrained run, the ATF achieved the desired sortie rate of just over three sorties per aircraft per day, but the F-15 achieved only about 2.5 sorties per aircraft per day because of constraints that were built into the LCOM model. These constraints could be a function of availability of spares, failure rates, or task time distributions. The study chose to keep the LCOM models as they were and to accept the upper bounds of 3 sorties per day for the ATF and 2.5 for the F-15. The utilization rate for maintainers was computed as the maintenance manhours divided by the available manhours. Because maintainers must perform other duties as well as maintenance, the Air Force does not plan for 100% utilization. For example, Tactical Air Command (TAC) used 83% as the ceiling

for planned utilization rates. Available hours were 12 hours per day for 30 days for each member of a shift. The utilization rates were predictably small for the unconstrained run.

Due to resource limitations, multiple LCOM runs were made for only a few options. Since Monte Carlo simulations such as LCOM rely on random draws to determine outcomes, the results of a number of runs should be used to estimate expected outcomes. The results in Table 1 are from single runs, although results for the options that had multiple runs were very consistent.

Several different manning levels for the two shifts were run for both the independent and the composite alternatives. For the first independent run listed in Table 1, each shift for each aircraft was manned at the minimum manning level, that is, the number of airmen in the largest crew size for any task, i.e., two for each aircraft. With this manning, the F-15 sorties fell to 1310 or 1.82 sorties per aircraft per day. Also the utilization rate for the F-15 maintainers climbed to 85.3% which exceeds the ceiling used by TAC. Reducing the manning for ATF maintainers did not affect the number of ATF sorties flown. The R&M improvements for the ICNIA systems of the ATF reduced the workload to the point where minimum manning was sufficient to handle maintenance without undue delays.

Increasing the F-15 manning to three on the first shift for the second independent run yielded 1400 F-15 sorties for a rate of 1.94 per aircraft per day. The utilization rate declined to 73.8%, well under the ceiling. Note that the difference in the manhours and utilization rates for the ATF maintainers between independent runs one and two should disappear if the results of several runs were averaged for each column.

Other small increases in the F-15 manpower did not increase the number of sorties flown. Of course, the increases reduced the utilization rate because more manhours were available. Thus, the best manning for the independent alternative was the manning in the second independent run and F-15 performance was capped at just under two sorties per day per aircraft, which is less than the performance goal.

Table 1. LCOM Results for 30 Days and 24 F-15 and 24 ATF Aircraft

	Unconstrained	Independent 1	Independent 2	Composite 1	Composite 2
F15 Sorties	1784	1310	1400	1400	1388
F15 Sorties/day	2.48	1.82	1.94	1.94	1.93
ATF Sorties	2209	2209	2209	2206	2209
ATF Sorties/day	3.07	3.07	3.07	3.06	3.07
F15 Manhours	1603	1229	1329	1208	1184
ATF Manhours	823	984	894	1027	883
F15 to ATF Manhours	-	-	-	56	76
ATF to F15 Manhours	-	-	-	205	165
F15 Shift 1 Manpower	200	2	3	2	3
F15 Shift 2 Manpower	200	2	2	2	2
ATF Shift 1 Manpower	200	2	2	2	2
ATF Shift 2 Manpower	200	2	2	2	2
F15 Utilization Rate %	1.1	85.3	73.8	83.9	65.8
ATF Utilization Rate %	.6	68.3	62.1	71.3	61.3

The first composite run used two airmen for each shift for each aircraft. That manning allowed the F-15 to achieve 1400 sorties, the same as the second independent run. F-15 maintainers contributed 56 manhours to ATF maintenance and ATF maintainers spent 205 hours on the F-15. There was a net transfer of 149 hours from the ATF to the F-15 through cross utilization. The utilization rate for F-15 maintainers was 83.9%, right at the TAC ceiling. Cross

utilization of the ATF maintainers increased their utilization rate over that for the first independent run.

The second composite run used three airmen for the first F-15 shift, two for the second, and two for each shift for the ATF. The slight dip in F-15 sorties over the first composite run is due to the nuances of the random draws. If the study had used a number of runs and averaged the results, the achieved sorties for the ATF should be virtually the same in all columns of Table 1. The added manpower for the second run did not affect the number of sorties flown; it just reduced the utilization rates for both F-15 and ATF maintainers. The best manning for the composite alternative was two airmen per shift for each aircraft (the first composite run), although the F-15 utilization rate was at its ceiling.

A number of interesting ideas could be explored in the future. For instance, runs could be made with less than minimum manning for each aircraft on at least one of the shifts to determine whether cross utilization could compensate. In this case, cross utilization would not just be optional, but would be required for tasks with maximum crew size. Another idea is to have one way cross utilization with airmen from the newer, more reliable aircraft providing maintenance on the older aircraft. In this study, this approach would allow the ATF maintainers to work on the F-15, but would restrict the F-15 maintainers to just the F-15. Since many of the first group of ATF maintainers would likely come from the F-15, the cross training might cost even less than estimated for this study. A third idea is to study the effect of the number of cross trained tasks on the manpower savings. Cross utilization provides opportunities to apply unused capacity for one aircraft to the other, and the more tasks that are cross trained, the more opportunities there should be to cross utilize the airmen. Ultimately, as the number of cross trained tasks increases, the two AFSs would essentially become one.

3.2. Training Requirements

The study linked training requirements to items of equipment specified by two or three-digit WUC. The primary measure of training requirements was hours of training by setting including technical training center (initial skills training), field training detachment (FTD), and on-the-job training (OJT).

3.2.1. Structure of Cross Training

The study concentrated on estimating cross training costs for the F-15 because its training data were readily available. Training data were more difficult to obtain and to analyze for the ATF which had a Navy aircraft, F-18, as its BCS. The study assumed cross training for the ATF was similar in structure, length, and cost to that for the F-15.

During the time period of the study, training for the primary AFS for F-15 Comm/Nav/Pen Aids flightline maintenance, 452X1C, consisted of an initial skills course at Lowry AFB, an FTD course at Eglin AFB, and OJT. According to the Occupational Survey Report for AFSC 452X1C (USAFOMC, 1990b) the initial skills course lasted 110 days including a 42-day phase covering electronic principles and a 68-day phase on F-15 avionic communications, and the FTD course lasted 19 days.[16] Airmen were granted skill level three when they completed the FTD course. OJT requirements for the 452X1C were based on the Specialty Training Standard and any additional requirements levied by the unit. OJT requirements were specified by skill level starting with the requirements for upgrade to 5-level. The study assumed that training for the primary AFS for the ATF, 452XXC, was similar.

The Air Force conducts cross training in several settings including technical training center, FTD, and OJT. However, based on comments from a number of Air Force maintenance training subject matter experts (SMEs) interviewed during the study, the options for cross training only a portion of the tasks for a secondary aircraft were either a combination of FTD and OJT or just OJT.[17] They thought teaching a small course like the one proposed in the study at a technical training center was too expensive.

If the study only used OJT for cross training, all of the training identified had to be converted to OJT, thus raising the issue of whether the length of the training changed as a result. Some SMEs suggested that if initial skills or FTD training were moved to OJT, the length of the training should be increased because they thought OJT instructors are not as efficient as the

[16] As of 15 April 1992, the FTD course was eliminated and all material was taught at the technical training center at Lowry in a 94-day course consisting of a 42-day electronic principles phase and a 52-day avionics communications phase. Simulators and aircraft were moved to Lowry to support the new course.

[17] One training planner from HQ TAC suggested that the material from the initial skills and FTD courses should be taught in OJT using integrated courseware (ICW) that includes video presentations supporting an interactive environment for practicing maintenance skills.

instructors at a technical training center or an FTD. They recommended inflating training hours that were converted to OJT from courses taught at a technical training center or FTD.

Another approach to converting training between settings can be based on the methodology developed in AL/HRT's Training Decisions System (TDS) research project. TDS defines four training settings: technical training center, FTD, OJT, and Career Development Course; and four types of training: classroom, small group hands-on training, hands-on experience on the job, and self study. TDS used SME input to develop training allocation curves to convert training hours from one type of training to another. By examining the proportion of each type of training for an AFS at each setting, one can use the allocation curves to convert training from one setting to another. However, TDS allocation curves differ by AFS and have been developed for only a few AFSs. To use them, the study would have had to assume curves from another AFS applied to AFSC 452X1C and to gather data on the proportion of each type of training that was in each 452X1C course.

The study chose to use a combination of FTD and OJT for cross training in order to simplify the process of converting training from one setting to another. The study assigned the necessary portions of initial skills and FTD training to a FTD cross training course and the OJT portions to OJT cross training requirements. Rather than using allocation curves to estimate the length of FTD training that was converted from the initial skills course, the study assumed that the type of training would remain the same at the new setting (e.g. topics that were taught in the classroom at the center would also be taught in the classroom at FTD); therefore, initial skill course hours were converted one-for-one to hours in FTD. FTD and OJT hours did not need to be converted because the cross training course used the same setting and type of training that was used for the primary AFS.

3.2.2. Identifying Cross Training Requirements

Air Education & Training Command (AETC) produces a syllabus or Plan of Instruction (POI) for the courses it teaches. The POI lists the topics taught in the course and the course hours and supervised self-study hours allocated to each topic. The POIs for the initial skills and FTD courses for 452X1C airmen were the starting points for identifying the cross training requirements for skills and knowledge taught in those courses.

The study explored the possibility of using information from the Training Extract (USAFOMC, 1990a) produced by the USAF Occupational Measurement Center (USAFOMC) as a part of the OS process. The 452X1C Training Extract contained mappings of OS tasks to topics on the syllabus for each course. These mappings, which were done by instructors for each course, exhibited problems similar to other mappings examined by the study. Many of the topics in each POI had no OS tasks mapped to them, and some of the topics had multiple OS tasks mapped to them. The study considered using the mapping of OS tasks to LCOM tasks in conjunction with the mapping of OS tasks to the POI to relate training hours to LCOM tasks. However, the lack of one-to-one mappings between OS tasks and the POI and between OS and LCOM tasks caused the study to look for other options.

In trying to resolve the many-to-one and one-to-many relationships identified in the OS to LCOM mappings, the study looked at aggregating OS tasks and LCOM tasks to try to reduce the mappings to one-to-one. The results of the aggregation often led to combinations of all tasks associated with a three-digit or two-digit WUC set or system. Rather than attempting to redo the OS to POI and OS to LCOM mappings based on the aggregations, the study investigated mapping topics from the POI directly to three-digit and two-digit WUC sets or systems.

The study presented the POI for the initial skills course to SMEs and asked them to identify topics that were needed to perform maintenance on the UHF and IFF systems and that would not be taught in the initial skills course for the primary aircraft, the ATF. General knowledge and skills related to the two systems would not need to be covered again in cross training. Only those aspects of the F-15 UHF and IFF systems that were different from similar systems on the ATF would be included in the cross training course. The SMEs used percentages to indicate the proportion of the listed training hours they thought were required for the cross training course. For instance, they might have indicated that 25% of the hours needed to be cross trained when a topic was mostly general knowledge with some equipment specific aspects.

The study presented the POI for the initial skills course to four SMEs and asked them to estimate the number of hours required to teach UHF and IFF related topics from the F-15 initial skills course to AFSC 452XXC airmen who were already trained to the five level on the ATF. The POI for the initial skills course listed both classroom and supervised self-study hours for each topic. The average of the four SME estimates indicated that 49.6 classroom hours and 18.2 hours of supervised self-study should be included in the cross training course. These estimates were

about 25% of the 200.5 hours of classroom time and 68 hours of supervised self-study time listed in the POI. The survey results are presented in Appendix F.

The study also presented the POI for the FTD course to the four SMEs and asked them to identify topics required for cross training ATF ICNIA maintainers to maintain the F-15 UHF and IFF systems. The average of the four estimates was 28.2 hours, again about 25% of the 112 hours listed in the POI. See Appendix F for more detail on the survey results.

It seems reasonable to assume that the percentage of a course identified for cross training is a function of a number of factors including the percentage of the systems and sets maintained by the AFS that are identified for cross training (which is assumed to be proportional to the percentage of the KSAs that must be trained for the AFS) and the relative emphasis on general knowledge and skills versus equipment specific knowledge and skills. The second factor is important because the cross training students would already have received training on general knowledge and skills while being trained for their primary AFS. Given the relation assumed above, the consistency of the percentages across the initial skills and FTD courses was a little surprising. Several people interviewed during the course of the study indicated that initial skills courses for avionics were weighted toward general knowledge and skills, while the FTD courses were weighted toward equipment specific training requiring simulators, mock-ups and equipment. This difference between the two courses should have caused a higher percentage of the FTD course to be identified for cross training, but the study did not find a difference.

Identifying cross training requirements for F-15 OJT was more difficult because OJT is less standardized than initial skills and FTD training. Some AFSs have an Air Force Job Qualification Standard (JQS) which lists tasks that must be trained for an airman to be upgraded to the 5, 7, or 9-level, but AFS 452X1C did not have a JQS. When there is no JQS, tasks that should be trained in OJT are identified in the Specialty Training Standard (STS) for the AFS. These tasks are listed on an airman's OJT record, Air Force Form 623. The unit decides what level of mastery of each task is required for upgrade to the 5, 7, or 9-level and may also add tasks to the OJT record that are not on the STS. Thus OJT can assume a local flavor, differing from one unit to another. Also, the OJT record does not assign a training time to each task. Instead, airmen are trained to the level of proficiency or mastery specified in the OJT record for upgrade to the next skill level. The OJT instructor is responsible for determining when the airman has achieved the required proficiency.

The study used two approaches for identifying OJT requirements for cross training, a top-down approach and a bottom-up approach. The top-down approach first asked for the elapsed time spent in OJT upgrade training to the 5-level. It then asked for the percentage of each day in the period that time that was actually spent in OJT. It also asked for the percentage of the OJT time that was spent on UHF and on IFF systems, and finally for the percentage of the time on the UHF and IFF systems that was spent on each three-digit WUC set in the respective system. The second, bottom-up method asked each SME to identify tasks on the OJT record that were required for performing maintenance on the UHF and IFF systems. It then asked the SMEs to estimate the training time spent on each of the tasks. To help estimate the costs of OJT, the study also asked the one OJT instructor surveyed to estimate the student to instructor ratio for OJT. The study obtained estimates from two SMEs for both the top-down and the bottom-up approaches.

The results of the top down survey indicated that a typical upgrade period is 12 months with about 30% of the airman's time being spent in OJT. The percentage of OJT devoted to the UHF system was 10%; the percentage devoted to the IFF system was 25%. See Appendix F for detailed survey results including a breakout by three-digit WUC. When the SME percentages were applied to the upgrade period, the average estimate of OJT time was 57 hours for the UHF system and 146 hours for the IFF system.

The results of the bottom-up approach indicated that about 35 tasks on the OJT record should be included in cross training. The SMEs estimated that 38.75 hours of UHF OJT and 68.5 hours of IFF OJT were needed for cross training. The study chose to use the top-down results over those from the bottom-up approach for several reasons. The study gathered data from more SMEs for the top-down approach, providing more confidence in the results. Also, the lack of benchmark times for individual tasks or topics, such as the POI provided for the other estimates, contributed to a lack of consistency in the estimates for the two SMEs polled. See Appendix F for more details.

The study's limited survey of SMEs yielded training requirements data with, in some cases, wide variability. However, the primary issue here was not developing precise training requirements based on SME surveys. Rather, the study concentrated on the SME estimation process to see if the approach was a viable one. In all cases, the SMEs were comfortable and confident estimating training requirements. However, the validity of their estimates should be evaluated before a large data collection effort is begun. The study concluded that SME surveys

are an acceptable means for collecting training requirements data if the surveys are precisely worded and if a sufficiently large sample of SMEs is polled. Section 4.2, Training Costs, discusses the process used to convert these estimates of initial skills course hours, FTD hours, and OJT hours to training costs for a cross training course.

4. LIFE-CYCLE COSTS

4.1. Manpower Costs

The study estimated the costs of the differences in manpower between the two alternatives. To make the estimates, the study modified the Army Manpower Cost System (AMCOS) model, and then used the modified model, the Air Force Manpower Cost System (AFMCOS), to estimate manpower costs. The primary modifications were to replace Army data with Air Force data and to eliminate options that only applied to the Army. The next few sections briefly describe the LCC methodology and data used in AFMCOS and highlight the revisions made to AMCOS to produce this first version of AFMCOS.

4.1.1. Costs Included in AFMCOS

AFMCOS had several cost policy modules, each of which estimates a certain category of costs. These cost policy modules included the following:

- military compensation
- retired pay accrual
- selective reenlistment bonus
- special pays
- training
- recruiting
- medical support
- other benefits
- permanent change of station (PCS)
- officer acquisition
- GI Bill

In general, each module computed an average cost for each possible grade of airmen and officers. In some cases the averages were further broken out by AFS. Average costs were computed for two budget categories: military personnel account (MPA) and operations and maintenance (O&M). Each of the modules is discussed in turn.

Military compensation consisted of all variable costs that provide basic pay, basic allowance for quarters (BAQ), basic allowance for subsistence (BAS), and variable housing allowance (VHA). Average basic pay was determined for each grade as a weighted average of the basic pay for each year of service (YOS) for the grade using the fraction of the inventory in the YOS for the grade as the weight. Average BAQ was determined for each grade as a weighted average of the with and without dependents rates, where the weights are the fraction receiving each rate. Average BAQ is further weighted by multiplying by the fraction receiving BAQ in-cash (as opposed to BAQ in-kind for those who live in quarters provided by the government). Average BAS for each grade was assumed to be the in-cash rate for the grade even though some members receive BAS in-kind. Average VHA for each grade was computed as the weighted average of the VHA for each location where the weights were the fraction of the grade inventory at the location. Average VHA was weighted further by the fraction of the grade receiving BAQ in-cash. Weights used in AFMCOS were taken from AMCOS and thus were based on weights for the Army.

Retired pay accrual cost was determined for each grade as the average basic pay per grade multiplied by a cost percentage rate obtained from the DoD actuary. An alternate estimate available in AMCOS for use by the Army did not apply to the Air Force and thus was not included in AFMCOS.

Selective reenlistment bonuses were a function of the award level or multiplier, years of reenlistment, and basic pay. Current multipliers were included in AFMCOS for the AFSC of interest in the study, 452X1C, and were assumed to apply to the new AFSC, 452XXC, as well. The average basic pay for each grade and average length of reenlistment were used in the computation of the average reenlistment bonus for each grade. Average basic pay and average length of reenlistment were taken from AMCOS (Army) data. The actual costs of selective reenlistment bonuses were weighted by the probability that members receive the bonuses. Bonuses did not affect the proof of concept study because the multipliers for AFSC 452X1C were zero.

Special pays included a number of incentive pays such as hazardous duty, overseas allowance, and special duty assignment pay. AFMCOS used a separate computation to determine the average of each special pay by grade and AFS. These computations determined an average

pay assuming the pay was received and then weighted it by the probability of receiving the pay. Overseas allowance was the only special pay used in the proof of concept study.

Training costs included the costs of Basic Military Training (BMT), initial skills training, FTD training to award skill level three, skill progression training, undergraduate flight training, cost of training officer accessions, and the cost of professional military education (PME). The costs of BMT and the initial skills and FTD courses for AFSC 452X1C were taken from the ATC Cost Factors report (ATC,1990). All other training costs were based on Army data from AMCOS. Because the proof of concept study did not consider officer positions, the only training costs based on Army data used in the study were the costs of skill progression training and PME.

Recruiting costs were computed per recruit using data provided by Air Force Recruiting Service (RS) to determine the costs of recruiters, recruit processing costs, and RS operations costs. AFMCOS used DoD data to determine the Air Force share of "joint costs" including advertising, market research, and recruiting facilities. AFMCOS did not compute separate recruiting costs for high and low quality recruits as was done in AMCOS, as all recruits were considered to be high quality.

Medical support was computed as the sum of the costs of CHAMPUS and the costs of operating Air Force health care facilities. Average CHAMPUS costs per grade were computed from the average costs of CHAMPUS per active duty dependent times the average number of dependents for the grade. The costs of the Air Force medical force and facilities were attributed to their wartime support mission so only the costs of operating the health care facilities were accounted for in AFMCOS. These costs were prorated to each eligible person, members and dependents, and then were allocated by grade as a function of the average number of dependents for members in the grade. Army data from AMCOS were used in AFMCOS.

Other benefits included separation pay, clothing allowance, the government contribution to social security tax, survivor's benefit, MWR (morale, welfare, and recreation) benefits, and miscellaneous costs. The average costs of each of these benefits were computed for each grade based on the weighted average of their use and cost for the grade. Army data from AMCOS were used in AFMCOS.

Permanent change of station (PCS) costs were estimated for five categories of moves; rotational, operational, accession, training, and separation moves. The average cost of each

category of moves was taken from the USAF Cost and Planning Factors report (AFCSTC/OS, 1989). Air Force data on tour lengths and the distribution of 452X1C positions overseas and in CONUS were used to determine the probability of a move. Army data from AMCOS on the fraction of each grade which has dependents were used to estimate the effect of weight allowances on PCS costs.

Officer acquisition costs included costs such as advertising, scholarships, initial training, military pay and allowances for cadets and officer trainees, and operations and support costs for the Air Force Academy, Officer Training School, and Reserve Officer Training Corps. Average costs were computed per new officer using Army data from AMCOS. However, no officer positions were considered in the proof of concept study.

GI Bill costs are funded by the Veteran's Administration and thus may be suppressed for some applications of the model. The basic benefit is $300 per month for up to 36 months. Average costs were computed from expected usage rates and expected costs for each participant. Army data from AMCOS were used in AFMCOS.

4.1.2. Cost Computation

As airmen and officers flow through the personnel inventory, certain "investment" or "one-time" costs are incurred. These costs, such as the initial costs of recruiting and training airmen, benefit the Air Force throughout the member's career. AFMCOS amortizes these costs over the expected years of service for the member. The proof of concept study used data for AFSC 452X1C to compute expected years of service. With this treatment of "investment" costs, all costs become an average cost per position or person per year.

AFMCOS computed the costs for each year of the life of the weapon system using the manning structure for each unit and the fielding plan for the number of units for each year of the system life assumed for the study. Standard DoD inflation rates (around 4%) were used to adjust costs for future years. Standard DoD discount rates (10%) were then used to compute the present value of all costs over the life of the system. All costs were converted to 1992 dollars. AFMCOS includes an option that allows the user to directly compare the costs of two alternatives. The study used this option to compare the independent and composite maintenance alternatives studied.

4.1.3. Results

The LCOM results presented in Table 1 were for units of 24 F-15 and 24 ATF aircraft. The study assumed units were fielded according to the plan presented in Table 2. All units were retired by year 28.

Table 2. Fielding Plan for ATF and F-15 Squadrons

Year	Units	Year	Units	Year	Units
1	1	10	9	19	9
2	2	11	9	20	9
3	3	12	9	21	8
4	4	13	9	22	7
5	5	14	9	23	6
6	6	15	9	24	5
7	7	16	9	25	4
8	8	17	9	26	3
9	9	18	9	27	2

As noted in Section 3.1.2, the best manning for the independent alternative was to assign two airmen to each shift for each aircraft except for one of the F-15 shifts which had three airmen assigned. Also, the best option for the composite unit was to assign only two airmen for each aircraft for each shift. Thus the composite unit needed only four airmen compared to the five needed for the independent unit. Manpower standards were used to convert positions from the model into manpower spaces. The manpower standard used permits 244 hours per space per month. For the best independent option, the standard allowed eight spaces for the F-15 and six for the ATF. For the best composite option, the standard allowed six spaces for each type of aircraft. When nine squadrons of each aircraft were fielded, there was a difference of 18 spaces between the two alternatives with the composite alternative having fewer. Temporarily ignoring the additional cost of cross training airmen in the composite unit, AFMCOS estimated the

difference in the discounted costs of the manpower under the two alternatives at $8.038 million with the composite alternative being cheaper.[18]

4.2. Training Costs

The various components of training costs can be designated as fixed or variable. The study concentrated on variable costs which usually represent the cost of delivering training and are presented as cost per student. The study used published sources for the cost of ATC courses (HQ ATC, 1990) and developed its own estimates for OJT costs.

As with manpower costs, the study estimated the difference in the training costs between the two alternatives. The costs of initial skills and FTD training for the primary aircraft were included in AFMCOS as a part of the estimate of the cost of any differences in manpower between the two alternatives. In addition, the study considered the cost of cross training required in the second alternative. F-15 maintainers from AFSC 452X1C received cross training on their secondary aircraft, the ATF, and ATF maintainers from AFSC 452XXC received cross training on their secondary aircraft, the F-15.

The study assumed that airmen would be cross trained for their secondary aircraft after they had been upgraded to the 5-level for their primary aircraft. The study also assumed that cross training would cover all the training requirements for the 5-level for the two-digit WUC systems selected for cross training.

4.2.1. Estimating Costs of Initial Skills Training

The study estimated the cost of cross training by first estimating the cost of the cross trained portions of each course and OJT. To be consistent with the manpower costs, training costs were converted to 1992 dollars using standard DoD inflation rates.

ATC reported the cost of the initial skills course, for both the electronic principles and the avionics phases, as $12430 per graduate (HQ ATC, 1990). As mentioned in Section 3.2, for the time period covered by the study, the initial skills course consisted of a 42-day electronic

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[18] For simplicity, all positions were designated as requiring grade E5.

principles phase and a 68-day avionics phase. Prorating the cost to the cross training course raised a problem with accounting for all the hours in the course. The June 1989 POI used in the study only listed 268.5 hours (200.5 hours of classroom training and 68.5 hours of supervised self-study, for a total of 33.6 days) in the avionics phase instead of the 544 hours expected for 68 days of 8 hours each. The 452X1 training manager at Lowry was not familiar with the POI used in the study but said that the new POI accounts for all the hours in the new 94 day course (42 days for electronic principles and 52 days for avionics which now includes the material formerly taught in the FTD course). Therefore, the study assumed that the old POI accounted for all 68 days of avionics training and prorated the training costs as follows. Because 68 of 110 total days were spent on avionics, the cost of the avionics phase was estimated to account for 68/110 or about 62% of the total of $12430, i.e., $7684. As estimated in Section 3.2, the UHF and IFF cross training portions of the avionics phase accounted for 67.8 of 268.5 hours in the POI. Thus, cross training the UHF and IFF portions of the course was estimated to cost about 25% of $7684, which is $1940.

4.2.2. Estimating Costs of Field Training Detachment Training

The study was unable to find costs for the FTD course; however, the ATC Comptroller maintains cost factors for each week of FTD that can be applied to the length of a given FTD course to estimate its cost. Using the factor of $889 per week, the estimated cost of the FTD course was $3379. Similar to problems encountered with the POI for the initial skills course, the POI for the FTD course listed a total of 112 hours rather than the expected 152 hours (19 days x 8 hours). Again the study assumed that the POI accounted for the entire course. According to Section 3.2, the 28.2 hours identified for cross training were about 25% of the total. Thus the cost of cross training the UHF and IFF portions of the FTD course was estimated as 25% of $3379, or $851.

4.2.3. Estimating Costs of On-The-Job Training

Estimating the costs of OJT is a controversial topic. Some of the controversy is due to the fact that required maintenance is often performed while OJT is conducted. Most cost analysts think that time spent performing required maintenance should not be charged to OJT. However, the difficulty then becomes determining the crew size and time required for the maintenance as compared to that for maintenance done in conjunction with OJT. Routinely collected

maintenance data do not permit precise determination of which maintenance actions and time should be counted as OJT, nor do they permit a precise determination of student to instructor ratio for OJT. Therefore, the study used the estimates of time spent in OJT presented in Section 3.2. The study used an average of 1.5 students per instructor as the student to instructor ratio, based on SME estimates. The study followed the lead of TDS by computing the cost of OJT as the sum of the costs of student time, instructor time, and expendables (Rueter, 1989). The study did not identify any expendables for 452X1C OJT and thus assumed that no expendables were consumed. Because the study assumed that OJT would not occur until the airmen had been granted skill level five in their primary AFS, OJT students were assumed to be E4s with four years of service. The study assumed OJT instructors were E5s with six years of service. The hourly costs depend on which cost elements are included. The study used cost elements included in military compensation, money actually paid to the airmen monthly, to compute hourly costs. Military compensation includes basic pay, BAQ, BAS, and VHA.[19]

The components of military compensation can vary due to the number of dependents, location, and other factors. Using average values for the components, the study estimated the hourly costs to be \$9.87 for an E4 with four years of service and \$11.36 for an E5 with six years of service. Based on a student to instructor ratio of 1.5, the cost per hour of OJT is \$9.87 for the student plus \$7.57 for the instructor (1/1.5 x \$11.36) for a total \$17.44 per hour. Based on the top-down estimate of 57 hours for the UHF system and 146 hours for the IFF system, the total OJT cross training hours were 203 hours, giving a cost per student of \$3540 (203 hours x \$17.44/hour).

4.2.4. Estimating Total Training Cost

The total cost per student of the cross training course for the F-15 UHF and IFF systems was \$1940 for the initial skills portion, \$851 for the FTD portion, and \$3540 for the OJT portion for a total of \$6331. The study assumed there were no course development costs or training equipment purchases.

[19] According to (Rueter, 1989), TDS used only basic pay in computing hourly costs.

Training data were not readily available for the Navy's F-18, the BCS for the ATF ICNIA systems; therefore, the cost of ATF cross training was not estimated directly. Instead, the cost was simply assumed to be the same as the cost for F-15 cross training or $6331 per student.

Converting per student costs to LCCs requires consideration of the flow of airmen into the inventory for an AFS. Since this conversion process is already embedded in the AFMCOS model, the study used AFMCOS to estimate the LCCs of conducting F-15 and ATF cross training by creating two new AFSs, one for each aircraft. All data for the two new AFSs were same as those for AFSCs 452X1C and 452XXC, respectively, except that the cost of FTD was increased by $6331, the cost of the cross training course for the other aircraft. In its computations, AFMCOS prorated these costs over the expected length of service for an airman from the AFS which was based on data for AFS family, 452X1, which includes AFSC 452X1C. The study made AFMCOS runs with and without the cross training costs and compared them to estimate the LCC of the cross training courses. For the best composite option and fielding plan used in the study, AFMCOS estimated the LCC of cross training to be $872,000.

5. SUMMARY AND CONCLUSIONS

This section of the report summarizes the findings of the proof of concept study to determine which of the two alternatives has lower LCCs. The section also reaches conclusions on the larger goals of the effort: 1) to determine whether data exist to support the system of models proposed for SYSMOD, and 2) whether the conceptual framework for SYSMOD provides a sound basis for estimating the MPT resource requirements and LCCs of alternatives proposed during Concept Exploration. Finally, the section discusses the steps that should be taken in order to develop SYSMOD for Concept Exploration.

5.1. Summary of Comparison of the Two Alternatives

The study found the composite alternative to be less costly than the independent alternative. The composite alternative had a manpower savings of 8.038 million dollars which more than offset the additional cost of .872 million dollars for cross training yielding a net savings of 7.166 million dollars. In fact, the manpower savings were sufficient to offset training costs about nine times as large as those estimated in the study.

5.2. Conclusions on Goals for the Effort

The study found SYSMOD to be a viable approach for estimating the MPT LCC of systems evaluated during Concept Exploration. It found that data can be obtained to support the models needed to make the estimates and that the proposed conceptual framework is a sound one for the comparison of alternatives.

5.2.1. Data Availability

Three categories of data are required to support the models envisioned for SYSMOD. Reliability and maintainability (R&M) data are required to estimate the maintenance workload and manpower requirements. Training data are needed to estimate training requirements, particularly the lengths of training courses. Cost data and factors are also needed to estimate the LCCs of

meeting the manning and training requirements of the proposed aircraft and to estimate the cost of spares and support equipment, if necessary.

In a manner typical of Concept Exploration studies, this study used data from existing aircraft that served as the parent systems for the proposed aircraft.[20] Fairly well-developed procedures exist for extracting R&M data on existing systems. These procedures have evolved to support LCOM modeling for manpower studies. Previous studies have even developed LCOM data for non-Air Force aircraft such as the Navy F-18 considered in this study. Because the LCOM data structure is well established in the manpower community, the study chose to use LCOM data as its R&M data structure. The study did not find a ready source of training data; instead, the study developed its own training data based on existing Air Force data. The study used cost data from an existing Army manpower cost model, AMCOS, as a starting point. The study sought sources of Air Force specific cost data to replace some of the Army cost data. The study did not attempt to identify sources for cost data for spares, support equipment, training development, and training equipment.

After some false starts, the study chose to aggregate data to the three-digit WUC or set level. This was the least aggregated (most detailed) level that the study found to be feasible. The study had problems developing training requirements data in more detail (e.g. by task at the three-digit WUC). In fact, some training data can be broken out better at only the two-digit WUC level; however, the study developed reasonable methods for assigning the data to the three-digit WUC level. Because R&M data can be extracted with greater detail than the three-digit WUC level, aggregating them to the three-digit level is fairly straightforward. Manpower cost data presented few problems because manpower costs were only applied once manpower positions were estimated. Training costs presented problems similar to those discovered with training requirements data. The study developed methods for assigning the costs in proportion to requirements at the three-digit WUC level.

Reliability and Maintainability Data: The study used existing LCOM models as sources of R&M data on the parent systems for the study, the F-18 and F-15. These LCOM models specified tasks to the four-digit WUC level and tracked individual resources; thus, they were more detailed than the three-digit WUC level required for Concept-Exploration.

[20] New aircraft are often described as derivatives of an existing aircraft or parent system which serves as a model or source of data for early studies.

Training Data: The study found that training requirements data for initial skills and FTD courses could be extracted from the course POIs. The POIs were readily available from the ATC training manager for the courses or from the Training Extract developed by USAFOMC. Based on the limited data collection effort conducted as a part of the study, it appears that airmen from an AFS can associate training requirements with two and three-digit WUC systems and sets. Thus a comparison system data base could also contain training requirements data for ATC courses. A review of the SME responses indicated that a knowledgeable analyst could have made most of the associations as well. Developing training requirements data for OJT was more difficult because OJT training requirements are less well defined and are less detailed than those for initial skills and FTD courses. The study used the OJT record as a starting point for developing OJT training requirements data. However, tasks listed on an OJT record vary with the unit to which an airman is assigned and do not have a specified length of training. The study explored two methods, top-down and bottom-up, that could be used to develop OJT training requirements data based on SME judgments. The methods should be refined before they are used to gather data to stock a BCS data base with training data on parent systems. Refinements examined should include gathering data using group consensus rather than averaging individual estimates. As shown in Appendix F, SMEs differed on some of the items selected for cross training. Forming a group consensus may be a better approach for resolving the differences.

Cost Data: Collecting the manpower cost factors included in AMCOS is straightforward but time consuming because the factors are found in a number of different documents or are maintained in data bases belonging to a number of different offices. A one-time effort is required to identify the sources of the data; however, the data themselves must be updated periodically. Training cost factors are readily available from the *ATC Cost Factors Report* (ATC, 1990). The study explored a method for prorating costs to training hours that appeared to give reasonable results. Follow on efforts should work with the ATC Comptroller to refine the methods.

5.2.2. Soundness of Conceptual Framework

For SYSMOD to be viable, its conceptual framework must provide a sound basis for comparing alternatives. With R&M and training data available at a three-digit WUC level on parent systems, a BCS data base can be built to support SYSMOD models. SYSMOD could include a data editor that allows the user to apply factors to the R&M data to change time

between failures, task times, or crew size to represent R&M improvements over the parent system. Similarly, training data could be edited by applying factors to change the length or cost of training over the parent system. The changes might anticipate increased efficiency in training delivery or a change in training hours due to a change in the KSAs that must be trained.

As mentioned earlier, the LCOM models used in the study were more complicated than required and so, more cumbersome. A simpler simulation or an analytic approximation is probably sufficient for estimating differences between proposed alternatives when available data are aggregated to the three-digit WUC level. The analytic methodology used in SUMMA may provide the foundation for estimating maintenance manpower in SYSMOD. Using analytic models with a three-digit WUC level of detail together with fairly constant sortie requirements should provide the consistency between models and data required to make good estimates.

Basing the LCC model for MPT costs on AMCOS or AFMCOS will provide a framework for estimating the three types of costs. Personnel costs such as those for recruiting and PCS moves and training costs are prorated over the member's expected service time to provide a basis for including them in the same model with the continuing costs of manpower. AFMCOS is flexible and easy to use and can be extended to include costs of spares, support equipment, training development, and training equipment.

Several tradeoff models appear to be feasible within the SYSMOD framework. The study of trades between R&M factors and manpower could be facilitated through the application of R&M factors to parent system data together with changing the manning levels for the AFSs. The study found that the manpower model should allow variable shift manning, including shifts with less than minimum manning. Otherwise, the impact of R&M improvements on manpower can be limited if the lower bound on shift manning is the minimum manning level.

AFS restructuring trades are also possible within the SYSMOD framework by shifting three-digit WUC sets of tasks between AFSs. More work must be done to investigate the effects on task performance time and training requirements, but until more is known, the model could make simplifying assumptions, such as the task time does not change and training requirements are independent and are therefore additive.

Other trades are readily included in the SYSMOD framework, but they depend on extending model capabilities beyond the first version of SYSMOD or on additional data

collection and analysis efforts. For instance, trades involving changes in the levels of maintenance depend on changes in R&M factors and in the supply of spares. The cost of spares must be included in the LCC model before this trade is effective. Another trade, one involving experience mix and manpower costs is dependent on more data regarding the relationship between performance time and experience. AL/HRM's productive capacity research is examining this issue.

5.2.3. Summary

The data required to support SYSMOD appear to be either available or obtainable through a modest data collection effort. The conceptual framework appears to be sound and within reach. The main question remaining is the choice of a simulation or analytic maintenance manpower model.

5.3. Next Steps in Building SYSMOD

A first version of SYSMOD could be started immediately.

- The BCS Data Base would contain data at the three-digit WUC level for a few existing systems, parent systems.

- Before the training requirements data for the data base are gathered, the collection methodology should be refined.

- Before the maintenance manpower model can be developed, a short study of simple simulation models and existing analytic models is needed to determine which approach is best.

- Development of the MPT LCC cost model, AFMCOS, could begin immediately.

- Limited versions of first tradeoff models could be based on input modification routines where the model helps anticipate and track the results of the modifications.

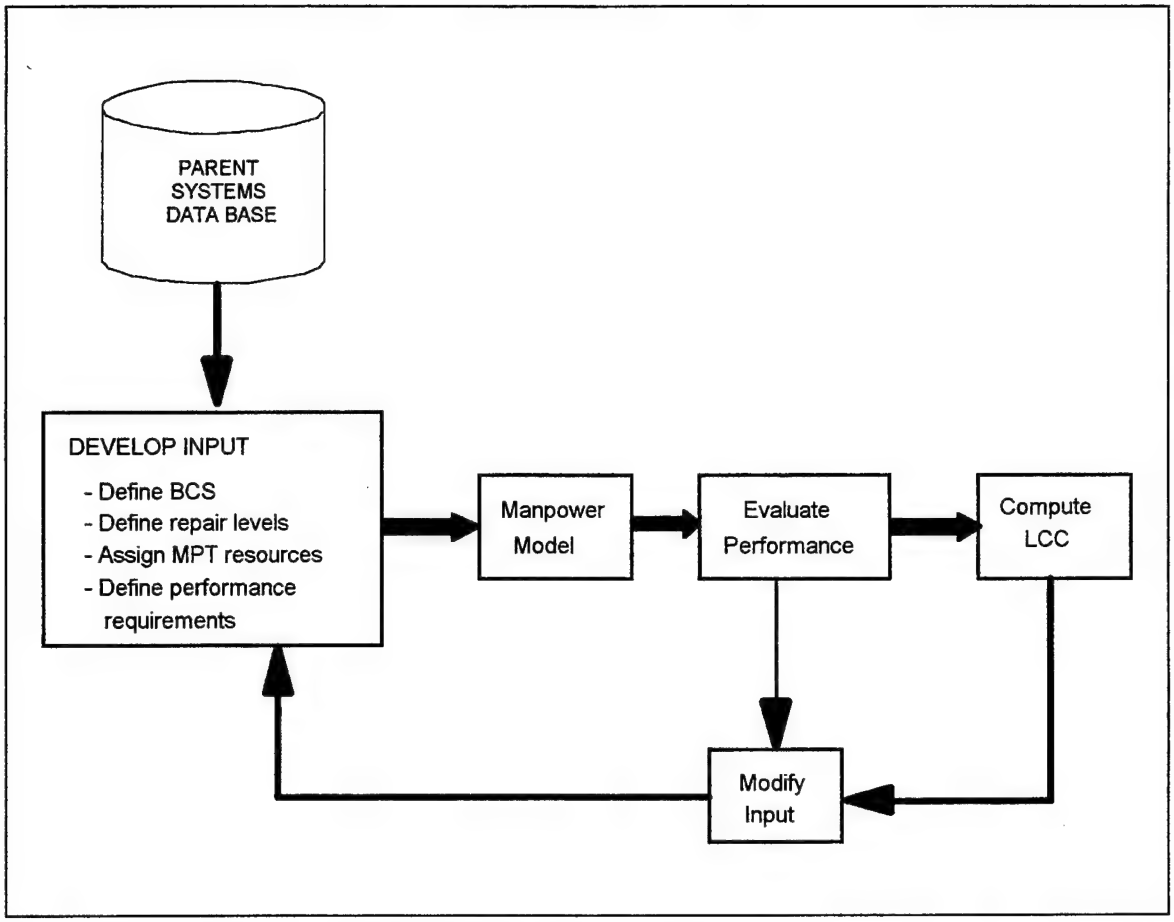

Figure 7. First Version of SYSMOD for Concept Exploration

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GLOSSARY

AFMCOS	Air Force Manpower Cost System
AFS	Air Force Specialty
AFSC	Air Force Specialty Code
AL/HRG	Armstrong Laboratories, Human Resource Dir, Logistics and Human Factors Div
AL/HRT	Armstrong Laboratories, Human Resource Dir, Training Systems Div
AL/HRM	Armstrong Laboratories, Human Resource Dir, Manpower & Personnel Div
AMCOS	Army Manpower Cost System
ATC	Air Training Command
ATF	Advanced Tactical Fighter
BAQ	Basic Allowance for Quarters
BAS	Basic Allowance for Subsistence
BCS	Baseline Comparison System
BMT	Basic Military Training
CHAMPUS	Civilian Health and Medical Program of the Uniformed Services
CODAP	Comprehensive Occupational Data Analysis Programs
FTD	Field Training Detachment
ICNIA	Integrated Communications-Navigation-Identification Avionics
ICW	Integrated Courseware
IFF	Identification Friend or Foe
JQS	Job Qualification Standard
KSA	Knowledge, Skills, and Abilities
LCC	Life-Cycle Cost
LCOM	Logistics Composite Model
LRU	Line Replaceable Unit
MA	Maintenance Action
MDCS	Maintenance Data Collection System
MPA	Military Personnel Account
MPT	Manpower, Personnel, and Training
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
MWR	Morale, Welfare, and Recreation

NRTS	Not Repairable This Station
OJT	On-the-Job Training
OS	Occupational Survey
PCS	Permanent Change of Station
PME	Professional Military Education
POI	Plan of Instruction
R&D	Research and Development
R&M	Reliability and Maintainability
RS	Recruiting Service
SAAT	Semantic Assisted Analysis Technology
SME	Subject Matter Expert
STS	Specialty Training Standard
SUMMA	Small Unit Maintenance Manpower Analyses
SYSMOD	Weapon System Optimization Model
TAC	Tactical Air Command
TDS	Training Decisions System
TLD	Task Learning Difficulty
USAFOMC	USAF Occupational Measurement Center
VHA	Variable Housing Allowance
WSAP	Weapon System Acquisition Process
WUC	Work Unit Code
YOS	Years of Service

APPENDIX A. F-15 LCOM TASK DATA

Table A-1 groups the LCOM tasks for AFSC 452X1C for the F-15 by three-digit WUC and displays the expected maintenance hours for each task resulting from flying 72 sorties per day. The three-digit WUC groups are displayed in order of the sum of the expected workload for all tasks in each group.

Table A-1. F-15 Expected Workload by Equipment WUC (Three-digit)

TASK	PROB	TASK TIME	CREW SIZE	MAINT HRS/ SORTIE	SORTIES /DAY	MAINT HRS/ DAY	TOTAL MHRS/ DAY/ WUC
H76H00	0.05118	1.5	2	0.15353	72	11.054	
M76H00	0.01765	1.2	2	0.04235	72	3.049	
R76H00	0.07500	1.7	2	0.25500	72	18.360	
T76H00	0.04294	0.5	2	0.04294	72	3.092	
V76H00	0.04897	0.5	2	0.04897	72	3.526	
X76H00	0.04132	1.5	2	0.12397	72	8.926	
T76H01	0.01471	0.5	2	0.01471	72	1.059	49.07
H76G00	0.06609	1.5	2	0.19827	72	14.276	
M76G00	0.01136	1.5	2	0.03409	72	2.455	
R76G00	0.01345	1.7	2	0.04575	72	3.294	
T76G00	0.01164	0.7	2	0.01629	72	1.173	
V76G00	0.01391	0.5	2	0.01391	72	1.002	
X76G00	0.00045	1.7	2	0.00155	72	0.111	22.31
H65B00	0.01495	1.5	2	0.04484	72	3.228	
M65B00	0.02911	1.2	2	0.06987	72	5.031	
R65B00	0.01150	1.5	2	0.03450	72	2.484	
T65B00	0.01567	1.0	2	0.03134	72	2.256	
V65B00	0.00745	0.3	2	0.00447	72	0.322	
X65B00	0.00356	1.3	2	0.00925	72	0.666	13.99
H63A00	0.01573	1.5	2	0.04719	72	3.398	
M63A00	0.00731	1.2	2	0.01754	72	1.263	
R63A00	0.01531	1.4	2	0.04286	72	3.086	
T63A00	0.01458	0.3	3	0.01312	72	0.945	
X63A00	0.00450	1.3	2	0.01170	72	0.842	9.53

TASK	PROB	TASK TIME	CREW SIZE	MAINT HRS/ SORTIE	SORTIES /DAY	MAINT HRS/ DAY	TOTAL MHRS/ DAY/ WUC
H65A00	0.00565	1.3	2	0.01470	72	1.058	
M65A00	0.03274	1.1	2	0.07203	72	5.186	
R65A00	0.00443	1.3	2	0.01153	72	0.830	
T65A00	0.01117	0.7	2	0.01564	72	1.126	
V65A00	0.00491	0.5	2	0.00491	72	0.354	
X65A00	0.00235	1.3	2	0.00610	72	0.440	8.99
H76A00	0.01125	1.5	2	0.03375	72	2.430	
M76A00	0.00153	1.2	2	0.00366	72	0.264	
R76A00	0.01213	1.7	2	0.04122	72	2.968	
T76A00	0.00670	0.7	2	0.00938	72	0.675	
V76A00	0.00595	0.5	2	0.00595	72	0.428	
X76A00	0.00433	1.5	2	0.01298	72	0.934	7.70
H63B00	0.00236	1.5	2	0.00709	72	0.511	
M63B00	0.00371	1.2	2	0.00890	72	0.641	
R63B00	0.01176	1.3	2	0.03058	72	2.202	
T63B00	0.00185	0.7	2	0.00260	72	0.187	
V63B00	0.00285	0.5	2	0.00285	72	0.206	
X63B00	0.00218	1.3	2	0.00567	72	0.408	4.15
H71D00	0.00482	1.5	2	0.01446	72	1.041	
M71D00	0.00030	1.3	2	0.00077	72	0.056	
R71D00	0.00307	1.4	2	0.00859	72	0.618	
T71D00	0.00234	0.7	2	0.00327	72	0.236	
V71D00	0.00146	0.5	2	0.00146	72	0.105	
X71D00	0.00058	1.3	2	0.00152	72	0.109	2.16
H71C00	0.00142	1.6	2	0.00454	72	0.327	
M71C00	0.00029	1.3	2	0.00074	72	0.054	
R71C00	0.00227	1.3	2	0.00589	72	0.424	
T71C00	0.00057	0.8	3	0.00136	72	0.098	
V71C00	0.00114	0.4	2	0.00091	72	0.065	
X71C00	0.00114	1.5	2	0.00341	72	0.245	1.21

TASK	PROB	TASK TIME	CREW SIZE	MAINT HRS/ SORTIE	SORTIES /DAY	MAINT HRS/ DAY	TOTAL MHRS/ DAY/ WUC
H71Z00	0.00177	1.5	2	0.00530	72	0.382	
R71Z00	0.00044	1.5	2	0.00133	72	0.096	
V71Z00	0.00133	0.5	2	0.00133	72	0.096	
X71Z00	0.00088	1.4	2	0.00248	72	0.178	0.75
R76C00	0.00103	1.5	2	0.00309	72	0.223	0.22

APPENDIX B. ATF LCOM TASK DATA

Table B-1 groups the LCOM tasks from the F-18 for the ATF ICNIA systems by three-digit WUC and computes the expected maintenance hours for each task resulting from flying 72 sorties per day. The three-digit WUC groups are displayed in order of the sum of the expected workload for all tasks associated with the three-digit WUC.

Table B-1. F-18 Expected Workload by Equipment WUC (Three-digit)

TASK	PROB	TASK TIME	CREW SIZE	MAINT HRS/ SORTIE	SORTIES /DAY	MAINT HRS/ DAY	TOTAL MHRS/ DAY/ WUC
V62X20	0.01048	1.90	2	0.03981	72	2.866	
H62X20	0.00434	0.87	2	0.00755	72	0.544	
T62X20	0.01482	1.78	2	0.05275	72	3.798	
M62X20	0.00356	1.32	2	0.00939	72	0.676	
R62X21	0.00675	1.65	2	0.02229	72	1.605	
R62X29	0.00003	2.30	2	0.00013	72	0.009	
R62X2C	0.00006	2.80	2	0.00031	72	0.022	9.52
V71D10	0.00293	1.90	2	0.01114	72	0.802	
M71D10	0.00148	2.04	2	0.00603	72	0.434	
R71D10	0.00008	6.93	2	0.00113	72	0.081	
H71D10	0.00105	0.77	2	0.00162	72	0.117	
T71D10	0.00398	1.78	2	0.01418	72	1.021	
R71D11	0.00048	2.58	2	0.00250	72	0.180	
R71D12	0.00081	3.17	2	0.00512	72	0.368	
R71D18	0.00008	3.30	2	0.00054	72	0.039	3.04
M653A0	0.00096	1.64	2	0.00316	72	0.227	
V653A0	0.00316	1.90	2	0.01201	72	0.864	
T653A0	0.00420	1.78	2	0.01496	72	1.077	
H653A0	0.00104	0.84	2	0.00175	72	0.126	
R653A3	0.00220	1.72	2	0.00756	72	0.544	2.84
H65Y10	0.00089	0.75	2	0.00134	72	0.096	
M65Y10	0.00129	1.10	2	0.00284	72	0.205	
T65Y10	0.00391	1.78	2	0.01391	72	1.001	
V65Y10	0.00302	1.90	2	0.01146	72	0.825	
R65Y1W	0.00172	0.77	2	0.00265	72	0.191	2.32

TASK	PROB	TASK TIME	CREW SIZE	MAINT HRS/ SORTIE	SORTIES /DAY	MAINT HRS/ DAY	TOTAL MHRS/ DAY/ WUC
T722B0	0.00324	0.50	2	0.00324	72	0.233	
M722B0	0.00040	1.21	2	0.00097	72	0.070	
V722B0	0.00289	0.50	2	0.00289	72	0.208	
H722B0	0.00035	1.14	2	0.00079	72	0.057	
R722B1	0.00235	2.37	2	0.01116	72	0.803	
H722C0	0.00163	0.90	2	0.00293	72	0.211	
R722C1	0.00006	0.75	2	0.00009	72	0.006	1.59
T72Y10	0.00352	0.50	2	0.00352	72	0.254	
M72Y10	0.00117	2.25	2	0.00524	72	0.378	
V72Y10	0.00305	0.50	2	0.00305	72	0.220	
R72Y1A	0.00003	1.20	2	0.00007	72	0.005	
R72Y1F	0.00017	3.05	2	0.00101	72	0.073	
R72Y1H	0.00003	1.80	2	0.00010	72	0.007	
R72Y1V	0.00006	2.45	2	0.00027	72	0.019	
R72Y1W	0.00161	1.44	2	0.00463	72	0.333	1.29
T621K0	0.00171	1.78	2	0.00608	72	0.438	
R621K0	0.00023	1.16	2	0.00054	72	0.039	
V621K0	0.00087	1.90	2	0.00330	72	0.238	
M621K0	0.00064	2.11	2	0.00268	72	0.193	
H621K0	0.00084	0.80	2	0.00135	72	0.097	1.01
T66140	0.00141	1.78	2	0.00503	72	0.362	
M66140	0.00003	0.50	2	0.00003	72	0.002	
V66140	0.00141	1.90	2	0.00537	72	0.387	0.75
A74000	0.00202	2.49	2	0.01007	72	0.725	0.73
R64X11	0.00259	1.44	2	0.00747	72	0.538	
R64X12	0.00006	1.95	2	0.00022	72	0.016	0.55
H729D0	0.00040	0.97	2	0.00078	72	0.056	
R729D0	0.00003	0.70	2	0.00004	72	0.003	
R729D1	0.00026	3.57	2	0.00183	72	0.132	
R729D9	0.00003	1.00	2	0.00006	72	0.004	0.20
V72RA0	0.00043	0.50	2	0.00043	72	0.031	
M72RA0	0.00032	2.82	2	0.00180	72	0.130	
T72RA0	0.00045	0.50	2	0.00045	72	0.033	0.19

TASK	PROB	TASK TIME	CREW SIZE	MAINT HRS/ SORTIE	SORTIES /DAY	MAINT HRS/ DAY	TOTAL MHRS/ DAY/ WUC
R71Y91	0.00009	4.17	2	0.00076	72	0.054	
R71Y92	0.00064	1.43	2	0.00182	72	0.131	
R71Y95	0.00003	0.70	2	0.00004	72	0.003	0.19
M63510	0.00016	0.95	2	0.00030	72	0.022	
V63510	0.00021	1.90	2	0.00081	72	0.058	
R63510	0.00003	1.40	2	0.00007	72	0.005	
T63510	0.00037	1.78	2	0.00133	72	0.096	
R63511	0.00003	0.50	2	0.00003	72	0.002	0.18
R713V0	0.00012	1.27	2	0.00029	72	0.021	
H713V0	0.00046	0.98	2	0.00090	72	0.065	
R713V3	0.00015	2.55	2	0.00078	72	0.056	0.14
R63Y2S	0.00013	4.82	2	0.00128	72	0.092	0.09
H632Z0	0.00028	1.04	2	0.00058	72	0.042	
R632Z6	0.00006	0.95	2	0.00011	72	0.008	0.05
H65000	0.00040	0.81	2	0.00065	72	0.047	0.05

APPENDIX C. CORRELATING LCOM TASKS WITH OS TASKS

C.1. Introduction

LCOM tasks are used by the manpower community as a structure for organizing manpower requirements and cost data. For example, maintenance time and crew size are identified with LCOM tasks to account for manpower needs. The study attempted to use OS tasks similarly as a structure for organizing training requirements and cost data. The STS is based upon the complete set of OS tasks for an AFS and is the starting point for developing POIs for formal training courses and for the Air Force JQS or OJT record. Then, to link manpower requirements or cost data with training requirements or cost data, the study had to correlate LCOM tasks with OS tasks. For instance, the study tried to tie training hours to LCOM tasks by first linking training hours to OS tasks and then mapping OS tasks to LCOM tasks to assign the hours to LCOM tasks.

C.2. Issues Affecting Correlation

In general, LCOM tasks are identified by two-component codes. The first component is a character which identifies the maintenance action (MA) to be performed, e.g. T indicates Troubleshoot. The second component is the WUC, a 5-position alphanumeric code which identifies the equipment requiring the maintenance action, e.g. 63A00 - UHF Communications Set.[21] Thus each LCOM task can be cleanly translated to a MA/WUC combination. OS tasks are identified by a letter followed by a sequence number. The letter groups tasks into general categories such as:

Performing General Avionics Systems Maintenance Tasks, and
Maintaining Comm/Nav/Pen Aids Systems

The two nomenclature systems do not lend themselves to direct correlation.

However, the two systems can be roughly correlated through task descriptions. OS task descriptions consist of an action verb and an object of the action. OS action verbs and LCOM maintenance actions can be mapped as shown in Table C-1 (Metrica, 1991). LCOM WUCs link directly to object descriptions in the Aircraft Maintenance Work Unit Code Manual (commonly referred to as the Dash 06). However, correlating object descriptions from OS tasks with WUC descriptions in the Dash 06 is a complicated process that ultimately affects the correlation of the two task structures. Because the

[21] WUCs are established and maintained independently of either LCOM or OS type data bases. The codes fill 2 to 5 digits of the 5-position task identifier, where a 2-digit code indicates one of the major systems of the aircraft, e.g. 63000 UHF Communications System; a 3-digit code indicates a set, e.g. 63A00 UHF Communications Set, which is part of the parent 2-digit WUC system; a 4-digit code indicates an LRU, e.g. 63AA0 UHF Receiver/Transmitter, which is part of the parent 3-digit WUC set; and the 5-digit code indicates an assembly, e.g. 63AAA Chassis Assembly, which is part of the parent 4-digit unit. WUCs and associated hardware are listed in the aircraft's B-4 Master File and in the Aircraft Maintenance Work Unit Code Manual.

two descriptions use neither the same terminology nor the same level of aggregation, these differences lead to problems in matching tasks.

Table C-1. Correlation of LCOM Actions and OS Verbs

LCOM ACTION TAKEN	OS VERB
Verify	Operationally check
Troubleshoot	Troubleshoot
Unscheduled remove and replace	• Disassemble • Remove or install
Repair in place/Minor maintenance	• Adjust • Calibrate • Repair/replace minor parts • Clean • Corrosion Repair
Cannot duplicate	Flightline check
Remove and replace to facilitate other maintenance	--

For example, the AFS 452X1C OS task list includes:

G278 Perform safety wiring

Safety wiring cannot be directly related to any one piece of equipment described in the Dash 06. Further, differences in aggregation lead to multiple matches. For example, the Semantic-Assisted Analysis Technology (SAAT) software developed by AL/HRM mapped the AFS 326X8C OS task - Isolate malfunction to UHF antenna - to the following WUCs and object descriptions from the Dash 06[22]:

63000 UHF Communication
63B00 Communication Set UHF
63BD0 Selector Antenna
63BE0 Antenna dual band upper

[22] The SAAT methodology is described in (Metrica, 1991). AFSC 326X8C was converted to AFSC 452X2C in 1988.

63BF0 Antenna dual band lower

Thus the OS task maps to five trouble shooting tasks, one for each WUC.

A second issue affecting the correlation of the two task structures is more fundamental. The maintenance and training communities have different perspectives on maintenance activities. The maintenance community takes a functional approach that is structured along WUC lines. It is concerned with the day-to-day maintenance of equipment, and the equipment fits neatly into the WUC structure. The training community is concerned about all tasks performed by members of the AFS, including non-maintenance tasks, and enabling members of the AFS to perform the tasks. Thus the training community takes a skills and knowledge approach that may cut across WUC boundaries or even be outside the WUC domain. The two communities slice maintenance activities into tasks differently. Sometimes there is not a one-to-one correspondence between the two slices.

C.3. Results

Since SAAT analysis had not been done on the 452X1C data, we correlated LCOM and OS tasks by hand. In doing so, we faced the issues identified above. We found LCOM tasks that had no corresponding OS task and others that had several. Conversely, we found OS tasks that had no corresponding LCOM task and others that had several. To improve our mapping, we had our results reviewed by an Air Force SME. The review eliminated problems we had relating object descriptions from the two systems, but it did not eliminate problems due to different levels of aggregation and the fundamental differences in orientation of the maintenance and the training communities.

The correlation between LCOM and OS tasks for AFS 452X1C is attached. (See Table C-2.) LCOM tasks are listed on the left-hand side and OS tasks along the right-hand side. WUC descriptions from the Dash 06 are in the middle.

C.4. Comments

The attached mapping and a similar one for the F-16 (452X2C) were the starting point for a number of analyses conducted in the study. The F-16 mapping was used to relate learning difficulty for OS tasks to SUMMA (LCOM) tasks in the regression studies on estimating task performance times for a secondary AFS. A proration scheme was used to handle the cases where several OS tasks mapped to a single LCOM task.

The study tried to use the F-15 mapping to link training hours to LCOM tasks in order to define the requirements for the cross training courses. A combination of problems led the study to modify the planned approach. First, the mapping of OS tasks to the POIs for the initial skills and FTD courses from the Training Extract (USAFOMC, 1990a) left some OS tasks unaccounted for and had some POI topics not linked to any OS tasks. These problems, compounded by the mapping problems between OS and

LCOM tasks, produced weak relationships between course hours and LCOM tasks. To minimize these problems, the study grouped tasks into sets that included all tasks associated with a three-digit WUC. Thus all OS tasks or all LCOM tasks concerned with the three-digit WUC were considered together. The study then had an SME map POI topics directly to three-digit WUC to identify the training requirements for each set of tasks. This eliminated some of the mapping problems. (See Section 3.2).

TABLE C-2. CORRELATION OF F-15 LCOM AND OS TASKS

LCOM	AFSC	ACTION TAKEN	WUC	SYSTEM	SUBSYSTEM	OS	OS NAME
R12A01X	326x8	Remove/repl	12A	Ckpt & fuse compts	Cockpit furnishings	NO MATCH	
NO MATCH			63A	UHF Communications	UHF Comm	J406	CODE SECURE VOICE CRYPTO EQUIP[23]
H63A00X	326x8	Cannot duplicate	63A	UHF Communications	UHF Comm	J408	ISOLATE MALFXNS TO SECURE VOICE CRYPTO EQUIP
						J420	ISOLATE MALFXNS W/IN UHF COMM & AUDIO SIGNAL SYS
						J432	PERFORM OP CKOUT & BIT OF UHF COMM & AUDIO SIGNAL SYS
						J434	PERFORM OP CKOUT & BIT OF SECURE VOICE CRYPTO EQUIP
M63A00X	326x8	Minor repair	63A	UHF Communications	UHF Comm	J408	ISOLATE MALFXNS TO SECURE VOICE CRYPTO EQUIP
						J420	ISOLATE MALFXNS W/IN UHF COMM & AUDIO SIGNAL SYS
						J432	PERFORM OP CKOUT & BIT OF UHF COMM & AUDIO SIGNAL SYS
						J434	PERFORM OP CKOUT & BIT OF SECURE VOICE CRYPTO EQUIP
R63A00X	326x8	Remove/repl	63A	UHF Communications	UHF Comm	J442	REMOVE/INSTALL SECURE VOICE CRYPTO EQUIP LRUS
						J449	REMOVE/INSTALL UHF COMM & AUDIO SIGNAL SYSTEM LRUS
T63A00X	326x8	Troubleshoot	63A	UHF Communications	UHF Comm	J408	ISOLATE MALFXNS TO SECURE VOICE CRYPTO EQUIP
						J420	ISOLATE MALFXNS W/IN UHF COMM & AUDIO SIGNAL SYS
						J432	PERFORM OP CKOUT & BIT OF UHF COMM & AUDIO SIGNAL SYS
						J434	PERFORM OP CKOUT & BIT OF SECURE VOICE CRYPTO EQUIP
X63A00X	326x8	Remove/repl to facilitate	63A	UHF Communications	UHF Comm	J449	REMOVE/INSTALL UHF COMM & AUDIO SIGNAL SYSTEM LRUS
						J442	REMOVE/INSTALL SECURE VOICE CRYPTO EQUIP LRUS
H63B00X	326x8	Cannot duplicate	63B	UHF Communications	Integrated CNI Cont[24]	J408	ISOLATE MALFXNS TO SECURE VOICE CRYPTO EQUIP
						J420	ISOLATE MALFXNS W/IN UHF COMM & AUDIO SIGNAL SYS
						J432	PERFORM OP CKOUT & BIT OF UHF COMM & AUDIO SIGNAL SYS
						J434	PERFORM OP CKOUT & BIT OF SECURE VOICE CRYPTO EQUIP
M63B00X	326x8	Minor repair	63B	UHF Communications	Integrated CNI Cont	J408	ISOLATE MALFXNS TO SECURE VOICE CRYPTO EQUIP
						J420	ISOLATE MALFXNS W/IN UHF COMM & AUDIO SIGNAL SYS
						J432	PERFORM OP CKOUT & BIT OF UHF COMM & AUDIO SIGNAL SYS

[23] 63BA0 Speech security unit KY 28, F-15A/B/C/D of 63A00 UHF Communications Set F-15A/B/C/D.

[24] 63B00 Integrated CNI Control Set is the control panel for 63000 UHF Communications and Joint Tac Info Dist Sys 71P (F-15C/D/E). Training necessary for performing 63A related tasks is also required for performing 63B tasks.

J434 PERFORM OP CKOUT & BIT OF SECURE VOICE CRYPTO EQUIP

LCOM	AFSC	ACTION TAKEN	WUC	SYSTEM	SUBSYSTEM	OS	OS NAME
M63B01X	326x8	Minor repair	63B	UHF Communications	Integrated CNI Cont	J408	ISOLATE MALFXNS TO SECURE VOICE CRYPTO EQUIP
						J420	ISOLATE MALFXNS W/IN UHF COMM & AUDIO SIGNAL SYS
						J434	PERFORM OP CKOUT & BIT OF SECURE VOICE CRYPTO EQUIP
						J432	PERFORM OP CKOUT & BIT OF UHF COMM & AUDIO SIGNAL SYS
R63B00X	326x8	Remove/repl	63B	UHF Communications	Integrated CNI Cont	J442	REMOVE/INSTALL SECURE VOICE CRYPTO EQUIP LRUS
						J449	REMOVE/INSTALL UHF COMM & AUDIO SIGNAL SYSTEM LRUS
T63B00X	326x8	Troubleshoot	63B	UHF Communications	Integrated CNI Cont	J408	ISOLATE MALFXNS TO SECURE VOICE CRYPTO EQUIP
						J420	ISOLATE MALFXNS W/IN UHF COMM & AUDIO SIGNAL SYS
						J432	PERFORM OP CKOUT & BIT OF UHF COMM & AUDIO SIGNAL SYS
						J434	PERFORM OP CKOUT & BIT OF SECURE VOICE CRYPTO EQUIP
V63B00X	326x8	Operationally ck	63B	UHF Communications	Integrated CNI Cont	J432	PERFORM OP CKOUT & BIT OF UHF COMM & AUDIO SIGNAL SYS
						J434	PERFORM OP CKOUT & BIT OF SECURE VOICE CRYPTO EQUIP
X63B00X	326x8	Remove/repl to facilitate	63B	UHF Communications	Integrated CNI Cont	J442	REMOVE/INSTALL SECURE VOICE CRYPTO EQUIP LRUS
						J449	REMOVE/INSTALL UHF COMM & AUDIO SIGNAL SYSTEM LRUS

LCOM	AFSC	ACTION TAKEN	WUC	SYSTEM	SUBSYSTEM	OS	OS NAME
NO MATCH			65A	IFF	Transponder Set	J405	CODE MODE 4 CRYPTO EQUIP[25]
H65A00X	326x8	Cannot duplicate	65A	IFF	Transponder Set	J407	ISOLATE MALFXNS TO MODE 4 CRYPTO EQUIP
						J410	ISOLATE MALFXNS W/IN AIR-TO-AIR IFF INTERROGATOR
						J412	ISOLATE MALFXNS W/IN IFF SYS
						J424	PERFORM OP CKOUT & BIT OF AAI SYS
						J426	PERFORM OP CKOUT & BIT OF IFF SYS
						J427	PERFORM OP CKOUT & BIT OF MODE 4 CRYPTO EQUIP
M65A00X	326x8	Minor repair	65A	IFF	Transponder Set	J407	ISOLATE MALFXNS TO MODE 4 CRYPTO EQUIP
						J410	ISOLATE MALFXNS W/IN AIR-TO-AIR IFF INTERROGATOR
						J412	ISOLATE MALFXNS W/IN IFF SYS
						J424	PERFORM OP CKOUT & BIT OF AAI SYS
						J426	PERFORM OP CKOUT & BIT OF IFF SYS
						J427	PERFORM OP CKOUT & BIT OF MODE 4 CRYPTO EQUIP
R65A00X	326x8	Remove/repl	65A	IFF	Transponder	J436	REMOVE/INSTALL AAI SYSTEM LRUS
						J439	REMOVE/INSTALL IFF SYSTEM LRUS
						J441	REMOVE/INSTALL MODE 4 CRYPTO EQUIP LRUS
T65A00X	326x8	Troubleshoot	65A	IFF	Transponder Set	J407	ISOLATE MALFXNS TO MODE 4 CRYPTO EQUIP
						J410	ISOLATE MALFXNS W/IN AIR-TO-AIR IFF INTERROGATOR
						J412	ISOLATE MALFXNS W/IN IFF SYS
						J424	PERFORM OP CKOUT & BIT OF AAI SYS
						J426	PERFORM OP CKOUT & BIT OF IFF SYS
						J427	PERFORM OP CKOUT & BIT OF MODE 4 CRYPTO EQUIP
V65A00X	326x8	Operationally ck	65A	IFF	Transponder Set	J424	PERFORM OP CKOUT & BIT OF AAI SYS
						J426	PERFORM OP CKOUT & BIT OF IFF SYS
						J427	PERFORM OP CKOUT & BIT OF MODE 4 CRYPTO EQUIP
X65A00X	326x8	Remove/repl to facilitate	65A	IFF	Transponder	J436	REMOVE/INSTALL AAI SYSTEM LRUS
						J439	REMOVE/INSTALL IFF SYSTEM LRUS
						J441	REMOVE/INSTALL MODE 4 CRYPTO EQUIP LRUS

[25] Mode 4 Crypto is recoded every 4 hours during wartime. Two codes are inserted to cover a potential switch to a new code during a mission. Recoding the Mode 4 Crypto is often the first step in troubleshooting as the problem with the unit can be that it did not receive the proper code. (e.g. Recognizes wingman as a bogey.)

LCOM	AFSC	ACTION TAKEN	WUC	SYSTEM	SUBSYSTEM	OS	OS NAME
H65B00X	326x8	Cannot duplicate	65B	IFF	IFF Int Set	J407	ISOLATE MALFXNS TO MODE 4 CRYPTO EQUIP
						J410	ISOLATE MALFXNS W/IN AIR-TO-AIR IFF INTERROGATOR
						J424	PERFORM OP CKOUT & BIT OF AAI SYS
						J427	PERFORM OP CKOUT & BIT OF MODE 4 CRYPTO EQUIP
M65B00X	326x8	Minor repair	65B	IFF	IFF Int Set	J407	ISOLATE MALFXNS TO MODE 4 CRYPTO EQUIP
						J410	ISOLATE MALFXNS W/IN AIR-TO-AIR IFF INTERROGATOR
						J424	PERFORM OP CKOUT & BIT OF AAI SYS
						J427	PERFORM OP CKOUT & BIT OF MODE 4 CRYPTO EQUIP
R65B00X	326x8	Remove/repl	65B	IFF	IFF Int Set	J436	REMOVE/INSTALL AAI SYSTEM LRUS
						J441	REMOVE/INSTALL MODE 4 CRYPTO EQUIP LRUS
T65B00X	326x8	Troubleshoot	65B	IFF	IFF Int Set	J407	ISOLATE MALFXNS TO MODE 4 CRYPTO EQUIP
						J410	ISOLATE MALFXNS W/IN AIR-TO-AIR IFF INTERROGATOR
						J424	PERFORM OP CKOUT & BIT OF AAI SYS
						J427	PERFORM OP CKOUT & BIT OF MODE 4 CRYPTO EQUIP
V65B00X	326x8	Operationally ck	65B	IFF	IFF Int Set	J424	PERFORM OP CKOUT & BIT OF AAI SYS
						J427	PERFORM OP CKOUT & BIT OF MODE 4 CRYPTO EQUIP
X65B00X	326x8	Remove/repl to facilitate	65B	IFF	IFF Int Set	J436	REMOVE/INSTALL AAI SYSTEM LRUS
						J441	REMOVE/INSTALL MODE 4 CRYPTO EQUIP LRUS

LCOM	AFSC	ACTION TAKEN	WUC	SYSTEM	SUBSYSTEM	OS	OS NAME
H71A00X	326x6	Cannot duplicate	71A	Radio Navigation	INS	NO MATCH	
M71A00X	326x6	Minor repair	71A	Radio navigation	INS	NO MATCH	
R71A00X	326x6	Remove/repl	71A	Radio navigation	INS	NO MATCH	
T71A00X	326x6	Troubleshoot	71A	Radio navigation	INS	NO MATCH	
V71A00X	326x6	Operationally ck	71A	Radio navigation	INS	NO MATCH	
X71A00X	326x6	Remove/repl to facilitate	71A	Radio navigation	INS	NO MATCH	
NO MATCH			71B	Radio Navigation	Direction Finder Group	J411	ISOLATE MALFXNS W/IN AUTO DIRECTION FINDER (ADF) SYS
NO MATCH			71B	Radio Navigation	Direction Finder Group	J437	REMOVE/INSTALL ADF SYSTEM LRUS
NO MATCH			71B	Radio Navigation	Direction Finder Group	J425	PERFORM OP CKOUT & BIT OF ADF SYS
H71C00X	326x8	Cannot duplicate	71C	Radio Navigation	ILS	J413	ISOLATE MALFXNS W/IN ILS
						J433	PERFORM OP CKOUT & BIT OF ILSS
M71C00X	326x8	Minor repair	71C	Radio navigation	ILS	J413	ISOLATE MALFXNS W/IN ILS
						J433	PERFORM OP CKOUT & BIT OF ILSS
R71C00X	326x8	Remove/repl	71C	Radio navigation	ILS	J440	REMOVE/INSTALL ILS LRUS
T71C00X	326x8	Troubleshoot	71C	Radio navigation	ILS	J413	ISOLATE MALFXNS W/IN ILS
						J433	PERFORM OP CKOUT & BIT OF ILSS
V71C00X	326x8	Operationally ck	71C	Radio navigation	ILS	J433	PERFORM OP CKOUT & BIT OF ILSS
X71C00X	326x8	Remove/repl to facilitate	71C	Radio navigation	ILS	J440	REMOVE/INSTALL ILS LRUS
H71D00X	326x8	Cannot duplicate	71D[26]	Radio navigation	TACAN(RT-1045/ARN F-15A/B)	J415	ISOLATE MALFXNS W/IN TACAN SYS
						J428	PERFORM OP CKOUT & BIT OF TACAN SYS
M71D00X	326x8	Minor repair	71D	Radio navigation	TACAN(RT-1045/ARN F-15A/B)	J415	ISOLATE MALFXNS W/IN TACAN SYS
						J428	PERFORM OP CKOUT & BIT OF TACAN SYS
R71D00X	326x8	Remove/repl	71D	Radio navigation	TACAN(RT-1045/ARN F-15A/B)	J443	REMOVE/INSTALL TACAN SYSTEM LRUS
T71D00X	326x8	Troubleshoot	71D	Radio navigation	TACAN(RT-1045/ARN F-15A/B)	J415	ISOLATE MALFXNS W/IN TACAN SYS
						J428	PERFORM OP CKOUT & BIT OF TACAN SYS
V71D00X	326x8	Operationally ck	71D	Radio navigation	TACAN(RT-1045/ARN F-15A/B)	J428	PERFORM OP CKOUT & BIT OF TACAN SYS
X71D00X	326x8	Remove/repl to facilitate	71D	Radio navigation	TACAN(RT-1045/ARN F-15A/B)	J443	REMOVE/INSTALL TACAN SYSTEM LRUS

[26] TACAN 71D or 71Z will be on the aircraft. 71Z is the newer model.

LCOM	AFSC	ACTION TAKEN	WUC	SYSTEM	SUBSYSTEM	OS	OS NAME
H71F00X	326x7	Cannot duplicate	71F	Radio navigation	AHRS	I345	ISOLATE MALFXNS W/IN AHRSS
						I370	PERFORM OP CKOUT & BIT OF AHRSS
R71F00X	326x7	Remove/repl	71F	Radio navigation	AHRS	I386	REMOVE/INSTALL AHRS LRUS
T71F00X	326x7	Troubleshoot	71F	Radio navigation	AHRS	I345	ISOLATE MALFXNS W/IN AHRS
						I370	PERFORM OP CKOUT & BIT OF AHRSS
V71F00X	326x7	Operationally ck	71F	Radio navigation	AHRS	I370	PERFORM OP CKOUT & BIT OF AHRSS
X71F00X	326x7	Remove/repl to facilitate	71F	Radio navigation	AHRS	I386	REMOVE/INSTALL AHRS LRUS
H71Z00X	326x8	Cannot duplicate	71Z	Radio navigation	TACAN(AN/ARN118)F-15A/B/C/D/E	J415	ISOLATE MALFXNS W/IN TACAN SYS
						J428	PERFORM OP CKOUT & BIT OF TACAN SYS
R71Z00X	326x8	Remove/repl	71Z	Radio navigation	TACAN(AN/ARN118)F-15A/B/C/D/E	J443	REMOVE/INSTALL TACAN SYSTEM LRUS
V71Z00X	326x8	Operationally ck	71Z	Radio navigation	TACAN(AN/ARN118)F-15A/B/C/D/E	J428	PERFORM OP CKOUT & BIT OF TACAN SYS
X71Z00X	326x8	Remove/repl to facilitate	71Z	Radio navigation	TACAN(AN/ARN118)F-15A/B/C/D/E	J443	REMOVE/INSTALL TACAN SYSTEM LRUS

LCOM	AFSC	ACTION TAKEN	WUC	SYSTEM	SUBSYSTEM	OS	OS NAME
H76A00X	326x8	Cannot duplicate	76A	TEWS	CM RCVR AN ALR 56	J409	ISOLATE MALFXNS TO TEWS RADAR WARNING RECEIVER (RWR)
						J431	PERFORM OP CKOUT & BIT OF TEWS RWRS
M76A00X	326x8	Minor repair	76A	TEWS	CM RCVR AN ALR 56	J409	ISOLATE MALFXNS TO TEWS RADAR WARNING RECEIVER (RWR)
						J431	PERFORM OP CKOUT & BIT OF TEWS RWRS
R76A00X	326x8	Remove/repl	76A	TEWS	CM RCVR AN ALR 56	J448	REMOVE/INSTALL TEWS RWR LRUS
T76A00X	326x8	Troubleshoot	76A	TEWS	CM RCVR AN ALR 56	J409	ISOLATE MALFXNS TO TEWS RADAR WARNING RECEIVER (RWR)
						J431	PERFORM OP CKOUT & BIT OF TEWS RWRS
V76A00X	326x8	Operationally ck	76A	TEWS	CM RCVR AN ALR 56	J431	PERFORM OP CKOUT & BIT OF TEWS RWRS
X76A00X	326x8	Remove/repl to facilitate	76A	TEWS	CM RCVR AN ALR 56	J448	REMOVE/INSTALL TEWS RWR LRUS
R76C00X	326x8	Remove/repl	76C	TEWS[27]	INTERF BLANKER SYS	J438	REMOVE/INSTALL IBS LRUS
NO MATCH			76C	TEWS	INTERF BLANKER SYS	J414	ISOLATE MALFXNS W/IN INTERFERENCE BLANKER SYS (IBS)
NO MATCH			76C	TEWS	INTERF BLANKER SYS	J421	PERFORM BIT OF IBSS
NO MATCH			76FBO	TEWS[28]	TEWS PODS CTRL PANEL	J418	ISOLATE MALFXNS W/IN TEWS EXTERNAL COUNTERMEAS SYS (ECMS) PODS
NO MATCH			76FBO	TEWS	TEWS PODS CTRL PANEL	J423	PERFORM BIT OF TEWS ECMSS (PODS)
NO MATCH			76FBO	TEWS	TEWS PODS CTRL PANEL	J445	REMOVE/INSTALL TEWS ECMS (PODS) LRUS
NO MATCH					-----------	J450	TRANSPORT TEWS ECMS (PODS)
NO MATCH					-----------	J451	UPLOAD OR DOWNLOAD TEWS ECMS (PODS)
H76G00X	326x8	Cannot duplicate	76G	TEWS	CMS AN/ALQ 128 EWWS	J417	ISOLATE MALFXNS W/IN TEWS ELECTRONIC WARFARE WARNING SYS (EWWS)
						J429	PERFORM OP CKOUT & BIT OF TEWS EWWSS
M76G00X	326x8	Minor repair	76G	TEWS	CMS AN/ALQ 128 EWWS	J417	ISOLATE MALFXNS W/IN TEWS ELECTRONIC WARFARE WARNING SYS (EWWS)
						J429	PERFORM OP CKOUT & BIT OF TEWS EWWSS
R76G00X	326x8	Remove/repl	76G	TEWS	CMS AN/ALQ 128 EWWS	J446	REMOVE/INSTALL TEWS EWWS LRUS
T76G00X	326x8	Troubleshoot	76G	TEWS	CMS AN/ALQ 128 EWWS	J417	ISOLATE MALFXNS W/IN TEWS ELECTRONIC WARFARE WARNING SYS (EWWS)
						J429	PERFORM OP CKOUT & BIT OF TEWS EWWSS
V76G00X	326x8	Operationally ck	76G	TEWS	CMS AN/ALQ 128 EWWS	J429	PERFORM OP CKOUT & BIT OF TEWS EWWSS
X76G00X	326x8	Remove/repl to facilitate	76G	TEWS	CMS AN/ALQ 128 EWWS	J446	REMOVE/INSTALL TEWS EWWS LRUS

27 LCOM should include troubleshoot and verify tasks for the 76C.

28 Only training wings have PODS.

LCOM	AFSC	ACTION TAKEN	WUC	SYSTEM	SUBSYSTEM	OS	OS NAME
NO MATCH			76H	TEWS	Cm AN/ALQ 135 V	J435	PERFORM PRESSURIZATION TESTS OF TEWS ICMSS
H76H00X	326x8	Cannot duplicate	76H	TEWS	Cm AN/ALQ 135 V	J419	ISOLATE MALFXNS W/IN TEWS INTERNAL COUNTERMEAS SYS (ICMS)
						J430	PERFORM OP CKOUT & BIT OF TEWS ICMSS
M76H00X	326x8	Minor repair	76H	TEWS	Cm AN/ALQ 135 V	J419	ISOLATE MALFXNS W/IN TEWS INTERNAL COUNTERMEAS SYS (ICMS)
						J430	PERFORM OP CKOUT & BIT OF TEWS ICMSS
R76H00X	326x8	Remove/repl	76H	TEWS	Cm AN/ALQ 135 V	J447	REMOVE/INSTALL TEWS ICMS LRUS
T76H00X	326x8	Troubleshoot	76H	TEWS	Cm AN/ALQ 135 V	J419	ISOLATE MALFXNS W/IN TEWS INTERNAL COUNTERMEAS SYS (ICMS)
						J430	PERFORM OP CKOUT & BIT OF TEWS ICMSS
T76H01X	326x8	Troubleshoot	76H	TEWS	Cm AN/ALQ 135 V	J419	ISOLATE MALFXNS W/IN TEWS INTERNAL COUNTERMEAS SYS (ICMS)
						J430	PERFORM OP CKOUT & BIT OF TEWS ICMSS
V76H00X	326x8	Operationally ck	76H	TEWS	Cm AN/ALQ 135 V	J430	PERFORM OP CKOUT & BIT OF TEWS ICMSS
X76H00X	326x8	Remove/repl to facilitate	76H	TEWS	Cm AN/ALQ 135 V	J447	REMOVE/INSTALL TEWS ICMS LRUS
NO MATCH			76K	TEWS	CM DISPENSER SET AN/ALE-45	J416	ISOLATE MALFXNS W/IN TEWS COUNTERMEAS DISPENSER SYS
NO MATCH			76K	TEWS	CM DISPENSER SET AN/ALE-45	J422	PERFORM BIT OF TEWS COUNTERMEAS DISPENSER SYS
NO MATCH			76K	TEWS	CM DISPENSER SET AN/ALE-45	J444	REMOVE/INSTALL TEWS COUNTERMEAS DISPENSER SYS

APPENDIX D. COMPUTATION OF MEASURES OF TASK CO-PERFORMANCE

D.1. Description of Co-Performance Computations

In the overlap program (OVRLAP) of the Comprehensive Occupational Data Analysis Programs (CODAP), task co-performance is defined as a measure of the similarity of pairs of task profiles across all the people in an occupational survey sample (Phalen, 1989). Since previous studies have found that co-performed tasks tend to require similar skills, knowledge, and abilities, this study used co-performance to identify sets of tasks for cross training in order to limit the costs of the cross training (Perrin, 1988 and Lamb, 1989).

CODAP Co-Performance Clustering: Co-performance clustering is a multi-step process carried out by CODAP. The steps are described through an illustrative example in a manner similar to that used for the co-performance measure in the Training Decisions System (Lamb, 1989).

Step 1: Figure D-1 is an example of a portion of a job inventory for AFS 452X1C (F-15 Communications, Navigation, and Penetration Aids Systems). Each person who completes the survey indicates the amount of time he or she spends on each task using a nine-point scale ranging from "very small amount" to "very large amount". These raw data are used to compute co-performance.

	CHECK	Time spent present job
	IF DONE NOW	RATE
		1. Very small amount. 2. Much below avg. 3. Below avg. 4. Slightly below avg. 5. About avg. 6. Slightly above avg. 7. Above avg. 8. Much above avg. 9. Very large amount.
A. Isolate malfunctions to secure voice crypto equipment		1 2 3 4 5 6 7 8 9
B. Perform ops checkout/BIT of UHF comm/audio signal systems		1 2 3 4 5 6 7 8 9
C. Remove or install secure voice crypto equipment LRUs		1 2 3 4 5 6 7 8 9
D. Remove or install UHF comm and audio signal systems		1 2 3 4 5 6 7 8 9

Figure D-1. Format of Job Inventory

Step 2: A case-oriented data file is developed that contains the responses from all the people (cases) surveyed. See Figure D-2 for a sample of ratings from an inventory.

	Case 1	Case 2	Case 3	Case 4
Task A	5	7	7	7
Task B	5	6	7	4
Task C	5	3	5	7
Task D	5	4	6	7
Total	20	20	25	25

Figure D-2. Case-oriented Data File from Job Inventory

Step 3: CODAP converts the entries in the case-oriented data file to percent time for each case. See Figure D-3. For example, Case 1 spends 25% of his or her time performing Task A. The total percent time is 100% for each case.

	Case 1	Case 2	Case 3	Case 4
Task A	25	35	28	28
Task B	25	30	28	18
Task C	25	15	20	28
Task D	25	20	24	28
Total	100	100	100	100

Figure D-3. Case-oriented Data File Converted to Percentages

Step 4: To conform to CODAP requirements, the data file must be transposed as shown in Figure D-4.

	Task A	Task B	Task C	Task D
Case 1	25	25	25	25
Case 2	35	30	15	20
Case 3	28	28	20	24
Case 4	28	18	28	28
Total	116	101	88	97

Figure D-4. Task-oriented Data File

Step 5: CODAP converts the entries in the task-oriented data file to percentages for each task due to each case. See Figure D-5. For example, 22% of the time spent on Task A by these four cases is spent by Case 1. The sum of the percentage values is 100% for each task.

	Task A	Task B	Task C	Task D
Case 1	22	25	28	26
Case 2	30	31	17	21
Case 3	24	28	23	25
Case 4	24	16	32	28
Total	100	100	100	100

Figure D-5. Task-oriented Data File as Percentage by Task

Step 6: The measure of co-performance between each pair of tasks is computed as the sum of the minimum entry for each case i as follows:

$$coperf_{btwn}^{task}(A,B) = \sum_{i=1}^{n} \min(A_i, B_i)$$

where

A_i = task A percentage for case i
B_i = task B percentage for case i
n = number of cases

Figure D-6 gives the co-performance measure for all pairwise combinations of tasks.
For example,

$$coperf_{btwn}^{task}(A,B) = 22+30+24+16=92$$

	Task A	Task B	Task C	Task D
Task A	100	92	86	91
Task B	92	100	81	87
Task C	86	81	100	94
Task D	91	87	94	100

Figure D-6. Co-performance Matrix for Four Groups

Step 7: Tasks C and D are identified as the first tasks to be clustered because they have the highest co-performance measure (94%). When CODAP merges tasks C and D, it computes a measure of group similarity called the co-performance "within" the new group. This measure is calculated as the average co-performance of each pairwise combination of tasks in the group including each task with itself. For the group CD, this computation is as follows:

$$coperf_{w/n}(CD) = \frac{coperf_{btwn}^{task}(C,C) + coperf_{btwn}^{task}(C,D) + coperf_{btwn}^{task}(D,C) + coperf_{btwn}^{task}(D,D)}{4}$$

thus,

$$coperf_{w/n}(CD)=\frac{(100+94+94+100)}{4}=97$$

A more meaningful measure of co-performance "within" would be one which excludes the overlap of each task with itself (i.e., 100%). Such a measure, which might be called *co-performance within** and be designated $coperf^{*}_{w/n}$, can be calculated for group CD using the following equation:

$$coperf^{*}_{w/n}(CD)=\frac{coperf^{task}_{btwn}(C,D)+coperf^{task}_{btwn}(D,C)}{2}$$

Thus,

$$coperf^{*}_{w/n}(CD)=\frac{94+94}{2}=94$$

However, since CODAP does not provide this calculation, the same result can be accomplished by using the $coperf_{w/n}$ from CODAP in the following equation:

$$coperf^{*}_{w/n}(...)=\frac{n[coperf_{w/n}(...)]-100}{n-1}$$

where n is the number of tasks in the group. Thus,

$$coperf^{*}_{w/n}(CD)=\frac{2(97)-100}{1}=94$$

Once CODAP computes the $coperf_{w/n}(CD)$, it then collapses rows C and D and columns C and D of the overlap matrix into a single row and column, thereby reducing the size of the matrix. This is done by computing a measure of the average co-performance "between" each task in the new group and each task in each of the remaining groups. For example, the co-performance between group CD and group A is computed as follows:

$$coperf_{btwn}(CD,A)=\frac{coperf^{task}_{btwn}(C,A)+coperf^{task}_{btwn}(D,A)}{2}$$

thus,

$$coperf_{btwn}(CD,A)=\frac{(86+91)}{2}=88.5$$

The co-performance between groups CD and B (i.e., $coperf_{btwn}(CD,B)$) is computed analogously. Figure D-7 gives the co-performance measures for the three remaining groups.

	Task A	Task B	Task CD
Task A	100	92	88.5
Task B	92	100	84
Task CD	88.5	84	97

Figure D-7. Co-performance Matrix after Combining Groups C and D

Step 8: Tasks A and B are identified as the next tasks to be merged because they now have the highest co-performance measure (92%). The co-performance within the new group is computed as follows:

$$coperf_{w/n}(AB)=\frac{coperf^{task}_{btwn}(A,A)+coperf^{task}_{btwn}(A,B)+coperf^{task}_{btwn}(B,A)+coperf^{task}_{btwn}(B,B)}{4}$$

thus,

$$coperf_{w/n}(AB)=\frac{(100+92+92+100)}{4}=96$$

and,

$$coperf^{*}_{w/n}(AB)=\frac{n[coperf_{w/n}(AB)]-100}{n-1}=\frac{2(96)-100}{1}=92$$

The co-performance between groups AB and CD is as follows:

$$coperf_{btwn}(AB,CD)=\frac{coperf^{task}_{btwn}(A,C)+coperf^{task}_{btwn}(A,D)+coperf^{task}_{btwn}(B,C)+coperf^{task}_{btwn}(B,D)}{4}$$

thus,

$$coperf_{btwn}(AB,CD)=\frac{(86+91+81+87)}{4}=86.25$$

Figure D-8 gives the co-performance measures for the two groups remaining.

Step 9: The next most similar pair is now the only remaining pair, groups AB and CD. The co-performance within the new group ABCD is as follows:

$$coperf_{w/n}(ABCD)=\frac{1}{16}\sum_{j=A}^{D}\sum_{k=A}^{D} coperf_{btwn}^{task}(j,k)$$

	Task AB	Task CD
Task AB	96	86.25
Task CD	86.25	97

Figure D-8. Co-performance Matrix for Two Groups

thus,

$$coperf_{w/n}(ABCD)=\frac{4(100)+2(92)+2(86)+2(91)+2(81)+2(87)+2(94)}{16}=91.38$$

and,

$$coperf^{*}_{w/n}(ABCD)=\frac{n[coperf_{w/n}(ABCD)]-100}{n-1}=\frac{4(91.38)-100}{3}=88.50$$

Figure D-9 gives the co-performance within the single group containing all four tasks.

	Task ABCD
Task ABCD	91.38

Figure D-9. Co-performance Measure for Single Group

Another value of interest is the average co-performance of each task in a group with every other task in the group, computed by the TASSET program in CODAP. For this final group of four tasks the average co-performance for task A is

$$coperf_{avg}(A) = \frac{coperf_{btwn}^{task}(A,B) + coperf_{btwn}^{task}(A,C) + coperf_{btwn}^{task}(A,D)}{3}$$

thus,

$$coperf_{avg}(A) = \frac{(92+86+91)}{3} = 89.67$$

Similarly,

$$coperf_{avg}(B) = \frac{(92+81+87)}{3} = 86.67$$

$$coperf_{avg}(C) = \frac{(86+81+94)}{3} = 87.00$$

$$coperf_{avg}(D) = \frac{(91+87+94)}{3} = 90.67$$

The range of these values gives a sense of the compactness of the group of tasks, 86.67% to 90.67% in this case. Also, if a single task were needed to represent the group, one choice would be the task with the highest average co-performance with all other tasks in the group (i.e., task D).

D.2. Co-Performance as Applied to F-15 COMM/NAV/PEN Aids Tasks

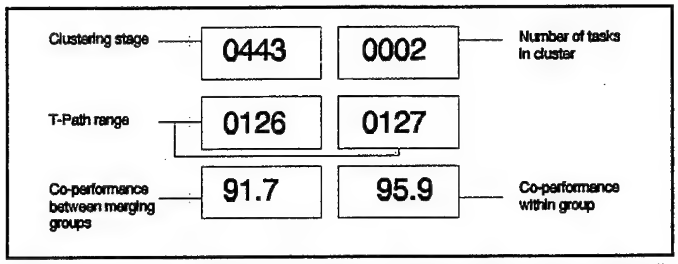

Figure D-10. CODAP Cluster Hierarchy Data Block

The study applied the hierarchical clustering techniques of the CODAP routines to F-15 COMM/NAV/PEN AIDS tasks performed by AFS 452X1C[29]. CODAP performed the initial clustering and displayed the results as a tree diagram composed of data blocks with the format shown in Figure D-10. The branches of the diagram traced the paths of individual tasks as they were combined into clusters and of the clusters as they were combined into larger clusters. (See Figure D-11.)[30]

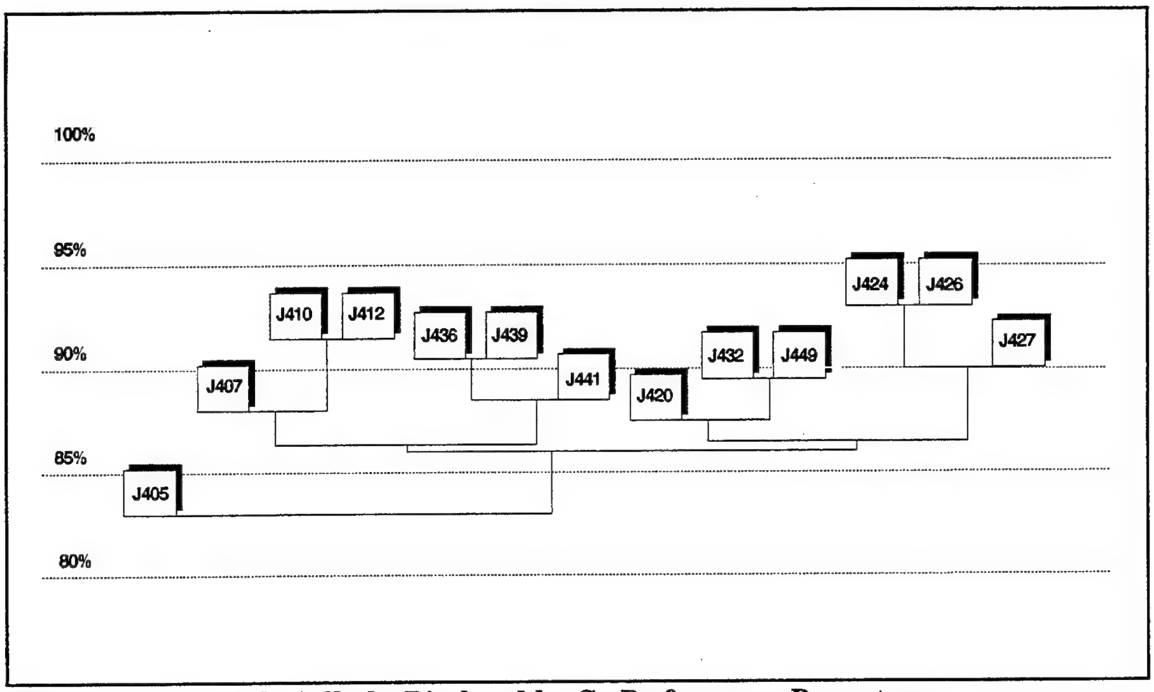

Figure D-11. Module A Tasks Displayed by Co-Performance Percentages

Using the tree diagram, we examined the CODAP output to evaluate clusters and group tasks to be handled together in cross training modules. We began by grouping task clusters based on a rough visual analysis of the tree diagram. Although this process tended to separate clusters into distinct groups

[29] CODAP was executed on 69 Occupational Survey (OS) tasks from CODAP study 9598 (conducted as a part of the occupational survey of the F-15 avionics systems career ladder in 1990), tasks with CODAP T-Path numbers 116 through 184, for people with 48 months of service or less. This range of tasks was chosen to include all 452X1C COMM/NAV/IFF tasks (T-Path numbers 124-161 and 176-184), identified in OS data as J tasks. Tasks with T-Path numbers 162-175 involve cables, wiring, and wave guides and are identified in OS data as G tasks. Miscellaneous other tasks were included in the cluster analysis because of their co-performance with the above tasks; they are T-Path numbers 116-123 which include 1 E task, 4 F tasks, and 3 G tasks.

[30] The tasks identified in Figure D-11 are connected by lines indicating the co-performance between tasks or groups when they merge. The positions and sizes of task blocks have no additional meaning.

by WUC, it did not necessarily aggregate clusters by WUC. This first cut associated the 69 tasks into 12 groups ranging in size from 1 task to 14 tasks. See Table D-1.

We revised the groups following a closer look at the tasks in each group and their associated WUCs. The final groups resulted from application of the following guidelines.

- In general, if groups containing multiple WUCs could be merged without increasing the variety of WUCs in the final group, they were merged. For example, three of the original groups (A,B,C) containing tasks for WUC 63, 63 and 65, and 63 respectively were combined to make the revised A group.

- Groups with common two-digit WUCs were not merged if combining the groups broadened the range of included three-digit WUCs. For example, Group H (originally Group J) contained only 76F tasks and was the only group to contain 76F tasks. It was not merged with other 76 groups.

- Groups with common WUCs were not merged if combining the groups caused a relatively large change in co-performance. For example, group A contains WUC 63 and 65 tasks, and group D contains WUC 63 tasks. The values of *co-performance within** those groups were 83.2% and 82.6% respectively; however, if the groups were combined, the co-performance between the merging groups was 66.1%. Therefore, we kept the two groups separate. See Table D-2 for measures of co-performance between and *co-performance within** groups.

The revised groupings are displayed as blocks in Figure D-12. The height of each block represents the range of the average co-performance measure of the tasks in the group with other tasks in the group (from TASSET). The width of each box represents the number of tasks included in the group. The vertical position of each horizontal line connecting two groups indicates the co-performance between the groups when the groups merge. For example, Group A contains 13 tasks having average co-performance measures from TASSET ranging from 83.2% to 87.8%, while Group D contains 4 tasks with average co-performance measures ranging from 82.6% to 84.4%. There are 7 major groups, A through E, G, and H, containing from 3 to 13 tasks each, specifically on COMM/NAV/PEN AIDS equipment. An eighth major group (F) contains 14 cable, wiring, and wave guide tasks. Two additional groups, X and Z, each with four tasks, contain safety tasks and miscellaneous other tasks.

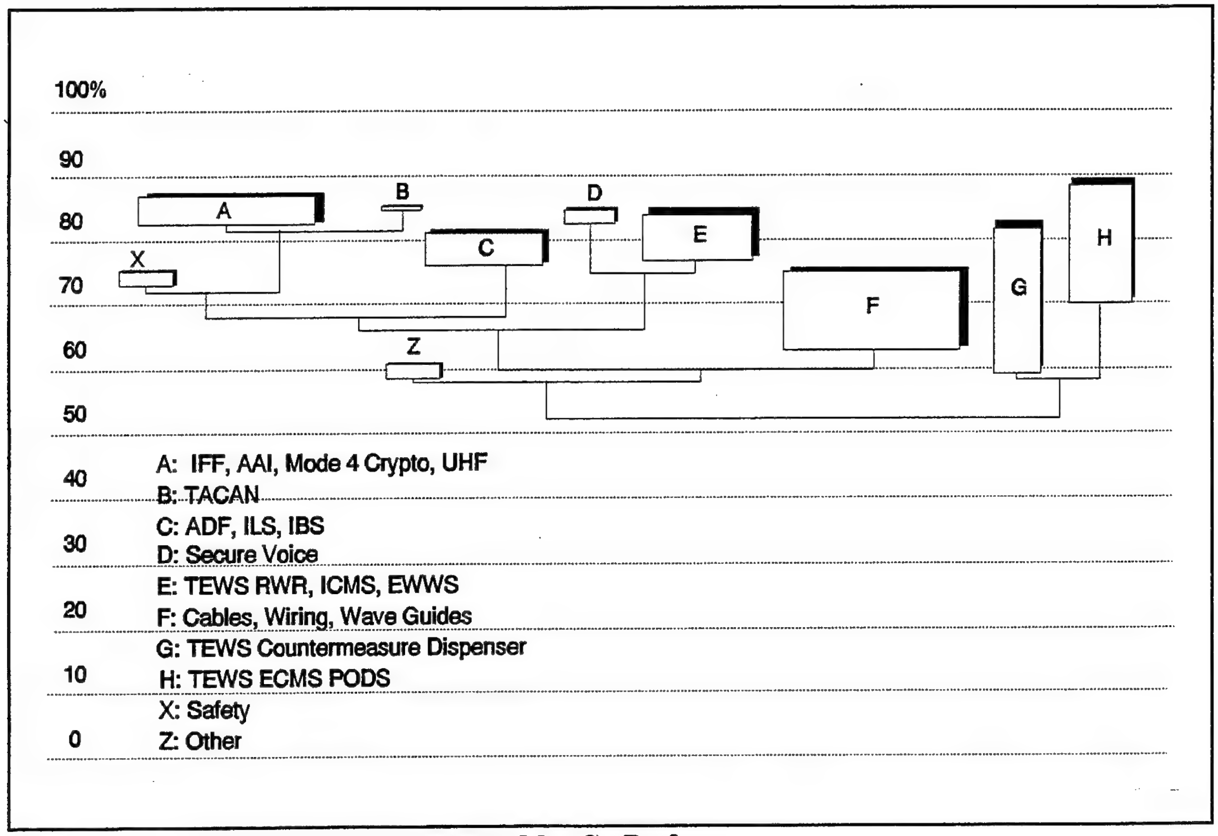

Figure D-12. F-15 OS Tasks Aggregated by Co-Performance

Average co-performance measures from TASSET for the tasks in each group are given in Table D-3.

Table D-1. Association of Tasks by Co-Performance

The Final Group column indicates the revised group assignments of OS tasks based upon WUCs. The Original Group column indicates the initial assignment of tasks to groups based on a rough visual examination of the cluster diagram output by CODAP.

FINAL GROUP	ORIG GROUP	CODAP T-PATH NUMBER	WUC	OS TASK NUMBER	OS TASK DESCRIPTION
A	A	125	65A,65B	J407	ISOLATE MALFUNCTIONS TO MODE 4 CRYPTO EQUIPMENT
	A	126	65A,65B	J410	ISOLATE MALFUNCTIONS WITHIN AIR-TO-AIR IFF INTERROGATOR (AAI) SYSTEMS
	A	127	65A,65B	J412	ISOLATE MALFUNCTIONS WITHIN IDENTIFICATION FRIEND OR FOE (IFF) SYSTEMS
	A	128	65A,65B	J436	REMOVE OR INSTALL AAI SYSTEM LINE REPLACEABLE UNITS (LRU)
	A	129	65A,65B	J439	REMOVE OR INSTALL IFF SYSTEM LRUS
	A	130	65A,65B	J441	REMOVE OR INSTALL MODE 4 CRYPTO EQUIPMENT LRUS
	B	131	63	J420	ISOLATE MALFUNCTIONS WITHIN ULTRA HIGH FREQUENCY (UHF) COMMUNICATION AND AUDIO SIGNAL SYSTEMS
	B	132	63	J432	PERFORM OPERATIONAL CHECKOUT AND BIT OF UHF COMMUNICATION AND AUDIO SIGNAL SYSTEMS
	B	133	63	J449	REMOVE OR INSTALL UHF COMMUNICATION AND AUDIO SIGNAL SYSTEM LRUS
	B	134	65	J424	PERFORM OPERATIONAL CHECKOUT AND BIT OF AAI SYSTEMS
	B	135	65	J426	PERFORM OPERATIONAL CHECKOUT AND BIT OF IFF SYSTEMS
	B	136	65	J427	PERFORM OPERATIONAL CHECKOUT AND BIT OF MODE 4 CRYPTO EQUIPMENT
	C	124	65	J405	CODE MODE 4 CRYPTO EQUIPMENT
B	D	137	71D,71Z	J415	ISOLATE MALFUNCTIONS WITHIN TACTICAL AIR NAVIGATION (TACAN) SYSTEMS
	D	138	71D,71Z	J428	PERFORM OPERATIONAL CHECKOUT AND BIT OF TACAN SYSTEMS
	D	139	71D,71Z	J443	REMOVE OR INSTALL TACAN SYSTEM LRUS
C	E	140	71B	J411	ISOLATE MALFUNCTIONS WITHIN AUTOMATIC DIRECTION FINDER (ADF) SYSTEMS
	E	141	76C	J414	ISOLATE MALFUNCTIONS WITHIN INTERFERENCE BLANKER SYSTEMS (IBS)
	E	142	71C	J413	ISOLATE MALFUNCTIONS WITHIN INSTRUMENT LANDING SYSTEMS (ILS)
	E	143	71B	J425	PERFORM OPERATIONAL CHECKOUT AND BIT OF ADF SYSTEMS
	E	144	71C	J433	PERFORM OPERATIONAL CHECKOUT OF ILSS
	E	145	76C	J421	PERFORM BIT OF IBSS
	E	146	71B	J437	REMOVE OR INSTALL ADF SYSTEM LRUS

FINAL GROUP	ORIG GROUP	CODAP T-PATH NUMBER	WUC	OS TASK NUMBER	OS TASK DESCRIPTION
C	E	-147	76C	J438	REMOVE OR INSTALL IBS LRUS
	E	148	71C	J440	REMOVE OR INSTALL ILS LRUS
D	F	149	63	J406	CODE SECURE VOICE CRYPTO EQUIPMENT
	F	150	63	J408	ISOLATE MALFUNCTIONS TO SECURE VOICE CRYPTO EQUIPMENT
	F	151	63	J434	PERFORM OPERATIONAL CHECKOUT OF SECURE VOICE CRYPTO EQUIPMENT
	F	152	63	J442	REMOVE OR INSTALL SECURE VOICE CRYPTO EQUIPMENT LRUS
E	G	153	76A	J409	ISOLATE MALFUNCTIONS TO TACTICAL ELECTRONIC WARFARE SYSTEM (TEWS) RADAR WARNING RECEIVERS (RWR)
	G	154	76A	J431	PERFORM OPERATIONAL CHECKOUT AND BIT OF TEWS RWRS
	G	155	76A	J448	REMOVE OR INSTALL TEWS RWR LRUS
	G	156	76H	J419	ISOLATE MALFUNCTIONS WITHIN TEWS INTERNAL COUNTERMEASURES SYSTEMS (ICMS)
	G	157	76H	J430	PERFORM OPERATIONAL CHECKOUT AND BIT OF TEWS ICMSS
	G	158	76H	J447	REMOVE OR INSTALL TEWS ICMS LRUS
	G	159	76G	J417	ISOLATE MALFUNCTIONS WITHIN TEWS ELECTRONIC WARFARE WARNING SYSTEMS (EWWS)
	G	160	76G	J446	REMOVE OR INSTALL TEWS EWWS LRUS
	G	161	76G	J429	PERFORM OPERATIONAL CHECKOUT AND BIT OF TEWS EWWSS
F	H	162		G265	INSPECT AIRCRAFT WIRING
	H	163		G267	INSPECT COAXIAL CABLES AND CONNECTORS
	H	164		G269	INSPECT MULTIPIN CONNECTORS
	H	165		G271	INSPECT WAVEGUIDES
	H	166		G266	INSPECT CHAFING PROBLEM AREAS
	H	167		G272	ISOLATE MALFUNCTIONS WITHIN AIRCRAFT WIRING
	H	168		G273	ISOLATE MALFUNCTIONS WITHIN COAXIAL CABLES AND CONNECTORS
	H	169		G275	ISOLATE MALFUNCTIONS WITHIN MULTIPIN CONNECTORS
	H	170		G288	REPAIR AIRCRAFT WIRING
	H	171		G280	REMOVE OR INSTALL COAXIAL CABLES
	H	172		G281	REMOVE OR INSTALL COAXIAL CONNECTORS
	H	173		G284	REMOVE OR INSTALL MULTIPIN CONNECTORS (CANNON PLUG)
	H	174		G289	REPAIR CHAFED AREAS
	H	175		G287	REMOVE OR INSTALL WAVEGUIDES

FINAL GROUP	ORIG GROUP	CODAP T-PATH NUMBER	WUC	OS TASK NUMBER	OS TASK DESCRIPTION
G	I	176	76_	J416	ISOLATE MALFUNCTIONS WITHIN TEWS COUNTERMEASURES DISPENSER SYSTEMS
	I	177	76_	J422	PERFORM BIT OF TEWS COUNTERMEASURES DISPENSER SYSTEMS
	I	178	76_	J444	REMOVE OR INSTALL TEWS COUNTERMEASURES DISPENSER SYSTEM LRUS
	I	179	76H	J435	PERFORM PRESSURIZATION TESTS OF TEWS ICMSS
H	J	180	76F	J418	ISOLATE MALFUNCTIONS WITHIN TEWS EXTERNAL COUNTERMEASURES SYSTEMS (ECMS)(PODS)
	J	181	76F	J445	REMOVE OR INSTALL TEWS ECMS (PODS) LRUS
	J	182	76F	J450	TRANSPORT TEWS ECMS (PODS)
	J	183	76F	J451	UPLOAD OR DOWNLOAD TEWS ECMS (PODS)
	J	184	76F	J423	PERFORM BIT OF TEWS ECMSS (PODS)
X	X	120		F186	CONNECT OR DISCONNECT AIRCRAFT EXTERNAL COOLING AIR UNITS
		121		F187	CONNECT OR DISCONNECT AIRCRAFT EXTERNAL POWER
		122		G277	PERFORM AIRCRAFT SAFE FOR MAINTENANCE CHECKS
		123		G278	PERFORM SAFETY WIRING
Z	Z	116		E130	INITIATE AFTO FORMS 350 (REPARABLE ITEM PROCESSING TAG)
		117		F232	POSITION OR REMOVE AIRCRAFT CHOCKS OR SAFETY PINS
		118		F261	WALK WINGS OR TAILS DURING AIRCRAFT TOWING OPERATIONS
		119		G263	ANALYZE AVIONICS STATUS PANEL (ASP) LATCH DATA

Table D-2. F-15 COMM/NAV/PEN AIDS Co-Performance

TASK RANGE START	TASK RANGE FINISH	CO-PERF BETWEEN MERGING GROUPS	CO-PERF WITHIN* GROUP	CLUSTERING STAGE	# TASKS IN CLUSTER	FINAL CLUSTER GROUP
126	127	91.7	91.7	0443	0002	A
128	129	90.7	90.7	0440	0002	A
132	133	89.7	89.7	0437	0002	A
134	135	92.8	92.8	0445	0002	A
138	139	86.7	86.7	0417	0002	B
140	141	86.3	86.3	0414	0002	C
143	144	82.8	82.8	0378	0002	C
146	147	87.6	87.6	0422	0002	C
151	152	86.3	86.3	0412	0002	D
154	155	90.0	90.0	0439	0002	E
157	158	89.9	89.9	0438	0002	E
159	160	84.7	84.7	0397	0002	E
163	164	85.2	85.2	0403	0002	F
167	168	88.2	88.2	0429	0002	F
171	172	87.9	87.9	0426	0002	F
176	177	81.6	81.6	0367	0002	G
182	183	88.2	88.2	0428	0002	H
125	127	88.1	89.4	0427	0003	A
128	130	88.4	89.2	0431	0003	A
131	133	87.7	88.3	0424	0003	A
134	136	89.6	90.7	0436	0003	A
137	139	85.7	86.1	0405	0003	B
140	142	85.0	85.5	0402	0003	C
146	148	83.2	84.7	0382	0003	C
150	152	84.1	84.9	0393	0003	D
153	155	87.3	88.3	0421	0003	E
156	158	89.2	89.5	0434	0003	E
156	158	89.2	89.5	0434	0003	E
159	161	82.6	83.4	0375	0003	E
162	164	81.4	82.8	0365	0003	F
167	169	84.4	85.6	0395	0003	F
171	175	80.3	82.9	0355	0003	F
176	178	78.6	79.6	0344	0003	G
181	183	85.3	86.2	0404	0003	H
149	152	82.6	83.7	0376	0004	D
162	165	75.3	78.9	0321	0004	F
167	170	80.4	83.1	0357	0004	F
176	179	69.2	74.4	0288	0004	G
180	183	75.9	81.1	0326	0004	H
140	144	79.4	81.5	0350	0005	C
162	166	73.0	76.6	0308	0005	F
180	184	70.2	76.8	0298	0005	H
125	130	86.1	87.3	0409	0006	A
131	136	86.9	88.0	0418	0006	A
140	145	78.2	80.4	0340	0006	C
153	158	83.0	85.4	0380	0006	E
167	173	76.9	79.5	0333	0007	F
140	148	77.5	79.3	0336	0009	C

TASK RANGE START	FINISH	CO-PERF BETWEEN MERGING GROUPS	CO-PERF WITHIN* GROUP	CLUSTERING STAGE	# TASKS IN CLUSTER	FINAL CLUSTER GROUP
153	161	76.7	80.9	0332	0009	E
176	184	59.5	66.8	0245	0009	G-H
125	136	86.0	86.8	0407	0012	A
162	173	69.6	73.8	0292	0012	F
124	136	83.2	86.2	0384	0013	A
149	161	75.0	78.3	0317	0013	D-E
162	174	64.4	72.4	0266	0013	F
162	175	63.3	71.0	0263	0014	F
124	139	82.3	85.0	0372	0016	A-B
120	139	73.2	81.0	0310	0020	A-B,X*
120	148	67.8	74.9	0282	0029	A-C,X
120	161	66.1	71.4	0278	0042	A-E,X
120	175	60.1	67.0	0250	0056	A-F,X
116	175	59.4	66.0	0244	0060	A-F,X,Z*
116	184	52.3	63.0	0213	0069	A-H,X,Z

* Co-performance measures are not shown for groups X and Z until they are combined with other groups.

Table D-3. Average Co-Performance from TASSET

GROUP	CODAP T-PATH NUMBER	OS TASK NUMBER	TASSET Average CO-PERF
A	125	J407	85.47
	126	J410	86.75
	127	J412	86.73
	128	J436	87.22
	129	J439	86.69
	130	J441	85.13
	131	J420	85.91
	132	J432	86.31
	133	J449	86.51
	134	J424	86.59
	135	J426	87.78
	136	J427	86.39
	124	J405	83.23
B	137	J415	85.72
	138	J428	86.23
	139	J443	86.15
C	140	J411	80.32
	141	J414	80.60
	142	J413	81.28
	143	J425	78.55
	144	J433	78.38
	145	J421	76.90
	146	J437	78.60
	147	J438	78.78
	148	J440	80.47
D	149	J406	82.60
	150	J408	84.13
	151	J434	83.76
	152	J442	84.41
E	153	J409	81.72
	154	J431	82.22
	155	J448	82.36
	156	J419	82.01
	157	J430	82.17
	158	J447	82.09
	159	J417	76.80
	160	J446	78.14
	161	J429	80.14

GROUP	CODAP T-PATH NUMBER	OS TASK NUMBER	TASSET Average CO-PERF
F	162	G265	71.25
	163	G267	71.80
	164	G269	71.77
	165	G271	69.57
	166	G266	67.68
	167	G272	75.44
	168	G273	75.43
	169	G275	74.60
	170	G288	73.55
	171	G280	72.19
	172	G281	73.60
	173	G284	70.83
	174	G289	64.02
	175	G287	63.34
G	176	J416	76.48
	177	J422	76.08
	178	J444	75.84
	179	J435	69.21
H	180	J418	74.67
	181	J445	80.15
	182	J450	78.61
	183	J451	79.96
	184	J423	70.22
X	120	F186	86.06
	121	F187	86.09
	122	G277	81.38
	123	G278	77.00
Z	116	E130	61.72
	117	F232	64.26
	118	F261	66.12
	119	G263	64.06

APPENDIX E. ESTIMATING TASK PERFORMANCE TIME FOR THE SECONDARY AFS

E.1. Introduction

When substituting cross trained personnel into maintenance crews for their secondary aircraft, one must consider how much longer, if at all, those personnel take to perform a maintenance task than do personnel who perform the task as a routine responsibility of their primary AFS.

To answer this question, we took the following steps. First, we searched for existing sources of primary and secondary AFS task performance times. We found that the SUMMA studies had gathered SME estimates of primary and secondary AFS task performance times for the F-18 and the F-16.[31] Second, we looked for measures of other factors likely to affect task performance times, i.e., task type (e.g. minor repair, remove and replace, troubleshoot, or verify), task learning difficulty, and specialty knowledge (e.g. mechanical, computer, fluids and gases, etc.). We found these data in the F-18 and F-16 SUMMA data bases and in the F-16 OS data base. Finally, we used regression analysis to identify relationships between secondary AFS task performance times and other quantifiable factors. The regressions, listed below, are detailed in the following sections:

F-18 Data Analyses:

- Regression of secondary time versus primary time
- Regression of mean-offset versus primary time
- Regression of secondary time versus primary time and task learning difficulty
- Regression of secondary time versus primary time and specialty knowledge factors

F-16 Data Analyses:

- Regression of secondary time versus primary time
- Regression of secondary time versus primary time and task learning difficulty (SUMMA)
- Regression of secondary time versus primary time and weighted task learning difficulty (OS)

[31] We planned to study primary and secondary task performance times for both aircraft, ATFs and F-15s, in the proof of concept study. However, F-15 data were unavailable, so we revised our study plan to include the F-16, for which a variety of high quality data exist.

E.2. F-18

We based our initial attempts to estimate secondary AFS task performance times on analyses of data collected as part of a SUMMA study conducted for the ATF in the mid-1980s. In that study, the ATF's ICNIA systems were represented by similar systems on the Navy's F-18. F-18 Electrician's Mates at Cecil Field, Florida estimated primary and secondary AFS task performance times and recorded their responses on a slightly modified version of the data collection instrument described in (Lamb, 1987). The Electrician's Mates answered 26 questions about 127 maintenance actions; two to four respondents considered each maintenance action. The maintenance actions included 11 minor repair (M) actions, 48 remove and replace (R) actions, 16 troubleshoot (T) actions and 52 verify (V) actions. The survey responses were aggregated as described in the referenced report. The resulting data base included mean respondent estimates of task performance time by primary AFS, task performance time by secondary AFS, task learning difficulty, and required mechanical, computer, electronics, fluids and gases, and metals characteristics knowledge.

On review of the data, we found that 43 of the 127 tasks had shorter secondary performance times than primary performance times. We have assumed that secondary AFS personnel will perform each task less frequently than primary AFS personnel and so will take longer to perform it. While there are several explanations for data showing short secondary performance times, e.g. respondent error, inaccurately stated survey instructions, or failure to properly account for secondary AFS inability to perform the task, all suggest survey problems rather than incompatibility with our assumption. Since we have no explanation for short secondary task performance times other than the possibility of data collection problems, we developed two modifications of secondary performance time, seca_hrs and secb_hrs, for use in our analyses.

Original data:	sec_hrs	= average estimated performance time for secondary AFS	
Modification 1:	seca_hrs	= max{sec_hrs,prim_hrs}	(43 of 127 modified)
Modification 2:	If sec_hrs < .5prim_hrs secb_hrs = prim_hrs Else secb_hrs = sec_hrs		(9 of 127 modified)

Regression of secondary time versus primary time: Our first analysis considered the relationship of secondary AFS task performance time to primary AFS task performance time (prim_hrs). Regressions for the three versions of secondary performance time, with and without intercepts, are

Table E-1. F-18 Regression Results

Secondary AFS Performance Time or Surrogate	Intercept	Coefficient of Primary AFS Task Performance Time (SUMMA)	Coefficient of Task Learning Difficulty (SUMMA)	r^2
1. sec_hrs	.7791	0.3897		.3538
2. sec_hrs		0.5019		.5233
3. seca_hrs	.1561	1.0210		.9444
4. seca_hrs		1.0435		.9602
5. secb_hrs	.1952	0.9512		.9114
6. secb_hrs		0.9793		.9367
7. secb_hrs (M tasks)		0.9620		.9381
8. secb_hrs (R tasks)		1.0576		.9449
9. secb_hrs (T tasks)		1.1943		.8768
10. secb_hrs (V tasks)		0.8712		.9557
11. m-offset	.1877	-0.0430		.0133
12. m-offset (M tasks)	.5719	-0.1752		.0203
13. m-offset (R tasks)	.2420	-0.0431		.0833
14. m-offset (T tasks)	.5126	-0.1078		.0044
15. m-offset (V tasks)	.0230	-0.0419		.0073
16. secb_hrs	-1.7462		1.3576	.0781
17. secb_hrs	.1578	0.9504	0.0139	.9114

displayed in Table E-1, equations 1 through 6. Notice that the equations with intercepts, in addition to having slightly lower r^2 values, make less sense. That is, when the primary AFS task performance time is zero, we expect the secondary performance time to be zero as well, giving an equation with no intercept. Also notice the regressions performed with the modified data seca_hrs and secb_hrs. The r^2 for the seca_hrs regression is slightly higher than that for the secb_hrs regression, as expected based on the modification to the data. However, we prefer to use the secb_hrs data. The modification to create that data set affected only 9 points where secondary performance time was less than half primary performance time and in our opinion, where the survey error explanation was more suitable.

We also evaluated secondary AFS task performance time versus primary AFS task performance time by maintenance action category. We regressed secondary performance time against primary performance time in the categories M (minor repair), R (remove/replace), T (troubleshoot), and V (Verify). While the data indicate that use of maintenance action category increases predictive ability in

some categories, they do not do so for all categories. We elected not to pursue this path at this time. (See Table E-1, equations 7 through 10.)

Regression of mean-offset versus primary time: We also considered the predictive ability of the mean-offset (m-offset), defined as the secondary AFS mean task performance time less the primary AFS mean task performance time, expressed in standard deviations from the primary AFS time:

$$\text{m-offset} = (\text{sec\_hrs} - \text{prim\_hrs})/(\text{std}_{\text{prim\_hrs}})$$

We also performed these regressions by task category, obtaining the results in Table E.6, equations 11 through 15. We did not consider the predictive ability of the mean-offset worth further analysis.

Regression of secondary time versus primary time and task difficulty: We evaluated the predictive ability of task difficulty using the mean of normalized SME task difficulty estimates (diff) from the F-18 SUMMA survey. We also considered the combined predictive ability of primary AFS task performance time (prim_hrs) and task difficulty (diff). (See Table E.1, equations 16 and 17 for the results.) Adding the difficulty measure did not increase the r^2. In fact, the r^2 adjusted for degrees of freedom is lower than the r^2 for the model using prim_hrs alone. These results discourage use of SUMMA task difficulty estimates as a task performance time predictor.

Regression of secondary time versus primary time and specialty knowledge factors: During the SUMMA survey, subject matter experts estimated the specialty knowledge required to perform each task. The experts estimated specialty knowledge requirements in the areas of computers, electronics, fluids and gases, metals, and mechanics. Their estimates were made on a 7 point scale; they were subsequently normalized to give a mean requirement of 4. Convinced of the value of primary AFS task performance time in predicting secondary AFS task performance time, we looked at the incremental increase to the regression's predictive ability brought by each specialty knowledge parameter. Table E-2 shows the incremental

Table E-2. Specialty Knowledge Variables

Variable Added	Partial r^2	Model r^2
prim_hrs	0.9112	0.9112
Mechanics	0.0012	0.9124
Metals	0.0004	0.9128
Fluids	0.0001	0.9129
Electronics	0.0000	0.9129
Computer	0.0000	0.9130

increase of r^2 when each of the specialty knowledge variables are added to the model[32]:

$$\text{secb\_hrs} = \text{intercept} + \text{prim\_hrs}$$

In all cases, the partial r^2 from the added variable was less than .0012. We did not pursue use of specialty knowledge for predicting task performance time.

Discussion: Several F-18 data issues were of concern. First, we questioned the quality of the F-18 survey data and were unable to verify it. The data had several weaknesses:

- The F-18 SUMMA results are based on data from a small number of respondents.
- The data include many outliers but the survey had no cross checks or other information for eliminating or "scrubbing" them.
- A third of the original task data sets showed secondary AFS task performance time less than primary AFS task performance time.

Empirical data for task performance times were not collected for comparison with the survey, and historical data are not readily available for comparison with the survey task data. Thus task performance time data are unverified.

A second concern is the possible bias in the survey data where respondents may supply the answers they think the researchers want. In this situation, Electrician's Mates might think someone else should perform the tasks, so they estimate shorter task performance times in order to influence the researchers toward giving the tasks to another rating (AFS). Finally, both survey instructions and intended responses can be misunderstood. For example, failure to supply a secondary AFS performance time can be an omission or an indicator that a secondary AFS cannot perform the task.

Based on F-18 SUMMA survey data, the best predictor of secondary AFS performance time is primary AFS performance time. However, we were concerned about the accuracy and reliability of our results 1) because of the survey's small sample size and wide ranging numbers and 2) because the slope suggested that personnel in a secondary AFS performed a task faster than personnel in the primary AFS. Suspecting that the slope might in fact be one, we performed a t-test on the data. Our results indicated that at a 95% confidence interval, the slope includes 1.0, so our choice for representing secondary AFS performance time for the F-18 is the equation below:

$$\text{secondary hours} = \text{primary hours}$$

[32] The regression for secb_hrs as a function of prim_hrs has a slightly different r^2 here because one point with missing values for the specialty knowledge variables was dropped from the regression.

E.3. F-16

We expanded our study to include analyses of F-16 data because 1) the F-18 SUMMA data were suspect, as discussed above, 2) F-15 data for the analyses were unavailable, and 3) F-16 data were readily available and wide ranging. We used primary and secondary AFS task performance time data from the F-16 SUMMA survey, reported in (Lamb, 1987). The F-16 study covered only 36 LCOM COMM/NAV tasks; however, approximately 40 SMEs responded to the survey, with 20-24 addressing each task. We converted SUMMA survey data to mean response for primary AFS performance time, secondary AFS performance time, and task difficulty. We attempted to validate the SME estimated performance times using LCOM data but our data set did not have historical performance times for the COMM/NAV tasks in the SUMMA survey.

Table E-3. F-16 Regression Results

Secondary AFS Performance Time	Intercept	Coefficient of Primary AFS Task Performance Time (SUMMA)	Coefficient of Task Learning Difficulty (SUMMA)	Coefficient of Weighted Task Learning Difficulty (OS)	r^2
1. sec_hrs	-0.0776	1.33			.9553
2. sec_hrs		1.24			.9882
3. sec_hrs	-1.4023		0.8133		.5609
4. sec_hrs			0.3166		.8463
5. sec_hrs	0.1061	1.42	-0.0888		.9578
6. sec_hrs		1.38	-0.0413		.9899
7. sec_hrs	-0.5484			.3413	.3030
8. sec_hrs				.2264	.8493
9. sec_hrs	-0.04323	1.38		-0.0092	.9791
10. sec_hrs		1.38		-0.0191	.9957

Regression of secondary time versus primary time: Our first analysis considered the relationship of the task performance time by the secondary AFS (sec_hrs) to that by the primary AFS (prim_hrs). Reviewing the data, we found only 1 of the 36 data points with a secondary performance time less than the primary performance time. Therefore, we made no modification to secondary performance times.

Regressions of secondary performance time against primary performance time, both with and without an intercept, are displayed in Table E-3. As with the F-18 analyses, we prefer the no-intercept

regression because it makes intuitive sense. (See Table E-3, equations 1 and 2.)

Regression of secondary time versus primary time and task difficulty (SUMMA): In the first portion of this analysis we considered the predictive ability of task difficulty, using the mean of normalized SME estimates of task difficulty (diff) generated during the F-16 SUMMA survey. The results, in equations 3 and 4 of Table E-3, have lower r^2 values than the regressions against primary time and so discourage use of SUMMA estimates of task difficulty alone as a task performance time predictor.

We also considered the combined predictive ability of primary AFS task performance time and task difficulty (diff). (See equations 5 and 6 of Table E.8.) Addition of the difficulty measure increases the r^2 slightly.

Regression of secondary time versus primary time and weighted task learning difficulty (OS): Another way to add task difficulty to the model is to use task learning difficulty (TLD) data from the OS data bases. If, in fact, TLD is a good predictor of secondary AFS task performance time, we will need TLD data for all systems of interest. OS data for TLD are available for all Air Force systems and are reliably based on hundreds of survey responses, where SUMMA survey data are available only for selected systems.

Thus, we used F-16 SUMMA survey data in conjunction with F-16 OS data as another way to study the combined predictive ability of primary AFS task performance time and task difficulty. TLD data are available by OS task for the F-16 Avionics AFS 452X1C and its predecessor 326X8C. We planned to use OS TLD in combination with SUMMA survey data, identified by LCOM task, to develop a regression as in the section above. We opted to use the older AFS 326X8 because we had a map of OS tasks to LCOM tasks provided developed using the Semantic-Assisted Analysis Technology (SAAT) (Metrica, 1991). (See Tables E-4 and E-5.) However, OS tasks do not match the maintenance actions of LCOM tasks on a one-to-one basis, as discussed in Appendix C. We applied the following rules in order to map the data for this analysis:

- When OS tasks were mapped to several levels of aggregation or WUCs, the mapping to the highest level LCOM task was retained. The mappings to LCOM tasks at a more detailed level were dropped.

- OS tasks which did not have a MA/WUC combination matching that generated by an LCOM task were ignored in this study.

These matches quickly led to a complicated mapping where one LCOM task could map to one, many, or no OS tasks, and one OS task could map to one, may, or no LCOM tasks. (See Tables E-6

and E-7.)

With the mapping complete, it was necessary to allocate the OS task learning difficulties to those LCOM tasks that had more than one OS task mapped to them. The approach we took was to weight the task learning difficulty of each OS task by the percent time spent performing the task.[33] The resulting weighted task learning difficulty (wgtd_ld) was the variable we used in the regression. The regression results in Table E-3, equations 5 through 8, are similar to the results using the SUMMA difficulty measures. TLD is not a strong predictor on its own and does not contribute enough to the predictive ability of primary time to make it a worthwhile addition to the predictive equation. In the task difficulty analyses, the two SUMMA and OS task difficulty measures played similar roles. However, as with the F-18 analyses, we do not consider task learning difficulty to be a worthwhile addition to the regression.

E.4. Summary

In general, we had more confidence in our F-16 analyses than the other work. The F-16 SUMMA data were based on the responses of 20-24 SMEs and showed more consistency.

Based on these studies, the best predictor of secondary AFS performance time is primary AFS performance time. At a 95% confidence interval, the slope does not include 1.0, so our choice for representing secondary AFS performance time for the F-16 is equation 2 in Table E-3, which is repeated below:

$$sec\_hrs = 1.24 \ prim\_hrs \qquad r^2 = .9882$$

[33] The weighting is similar to that used in computing Average Task Difficulty Per Unit Time Spent (ATDPUTS).

Table E-4. Derivation of F-16 Weighted Task Learning Difficulty - Step 1.
F-16 OS (Old) Tasks Identified by Metrica SAAT as Involving Work Units of the 65 or 76 Systems

OS TASK	MAINT ACTION/ WUC	TASK DIFFICULTY
197	V76E00	5.4556
199	V76E00	5.4126
207	_76EEG	5.5549
*224	V76EB0	1.8605
224	V76EA0	1.8605
644	V65AAF	2.4875
651	T65A00	5.7402
688	T65A00	5.5322
689	T65A00	5.4297
690	T65A00	5.3588
691	T65A00	5.4302
692	T65A00	5.2841
693	T65A00	5.5276
694	T65A00	5.0954
695	T65A00	5.0584
696	T65A00	4.9127
697	T65A00	4.9254
*713	V65A00	4.7198
713	V65AC0	4.7198
716	V65A00	4.8646
723	V65A00	3.9026
725	V65A00	4.7546
726	V65A00	4.5106
751	T76C00	5.4867
764	T76E00	5.7311
*765	T76EC0	6.0961
765	T76E00	6.0961
766	T76E00	6.0874
767	T76E00	6.4003
*768	T76EC0	5.7884
768	T76E00	5.7884
769	T76E00	5.8724
771	T76E00	5.5319
772	T76E00	6.7100
778	V76E00	4.9496
779	V76ED0	3.9828
780	V76E00	4.3643
785	V76E00	4.9671
*789	V76ED0	4.3065
789	V76EH0	4.3065
789	V76EE0	4.3065

* INDICATES ONE OS TASK MAPPED TO MULTIPLE MA/WUC COMBINATIONS.

Table E-5. Derivation of F-16 Weighted Task Learning Difficulty - Step 2.
Reorder F-16 OS (Old) Tasks by MA/WUC Combination

MAINT. ACTION/ WUC	OS TASK	TASK DIFFICULTY
_76EEG	207	5.5549
T65AA0	651	5.7402
T65A00	688	5.5322
	689	5.4297
	690	5.3588
	691	5.4302
	692	5.2841
	693	5.5276
	694	5.0954
	695	5.0584
	696	4.9127
	697	4.9254
T76C00	751	5.4867
T76E00	764	5.7311
	765	6.0961
	766	6.0874
	767	6.4003
	768	5.7884
	769	5.8724
	771	5.5319
	772	6.7100
T76EC0	765	6.0961
	768	5.7884
V65A00	713	4.7198
	716	4.8646
	723	3.9026
	725	4.7546
	726	4.5106
V65AAF	644	2.4875
V65AC0	713	4.7198
V76E00	197	5.4556
	199	5.4126
	778	4.9496
	780	4.3643
	785	4.9671
V76EA0	224	1.8605
V76EB0	224	1.8605
V76ED0	779	3.9828
	789	4.3065
V76EE0	789	4.3065
V76EH0	789	4.3065

Table E-6. Derivation of F-16 Weighted Task Learning Difficulty - Step 3. Consolidate OS Originating MA/WUC Combinations to LCOM MA/WUC Combinations

LCOM MAINT ACTION/ WUC	OS MAINT ACTION/ WUC	OS TASK	TASK DIFFICULTY
T65A00	T65AA0	651	5.7402
	T65A00	688	5.5322
		689	5.4297
		690	5.3588
		691	5.4302
		692	5.2841
		693	5.5276
		694	5.0954
		695	5.0584
		696	4.9127
		697	4.9254
V65A00	V65A00	713	4.7198
		716	4.8646
		723	3.9026
		725	4.7546
		726	4.5106
	V65AAF	644	2.4875
	V65AC0	713	4.7198
T76C00	T76C00	751	5.4867
T76E00	T76E00	764	5.7311
		765	6.0961
		766	6.0874
		767	6.4003
		768	5.7884
		769	5.8724
		771	5.5319
		772	6.7100
	T76EC0	765	6.0961
		768	5.7884
V76E00	V76E00	197	5.4556
		199	5.4126
		778	4.9496
		780	4.3643
		785	4.9671
	V76EA0	224	1.8605
	V76EB0	224	1.8605
	V76ED0	779	3.9828
		789	4.3065
	V76EE0	789	4.3065
	V76EH0	789	4.3065

Table E-7. Derivation of F-16 Weighted Task Learning Difficulty - Step 4. Eliminate Duplicate OS Task Mappings to Single LCOM Task; and Weight TLD by % Time Performing

	LCOM TASK	PRIM TIME	SEC TIME	WUC/ ACTION	OS TASK	TASK DIFF	%TIME	COMPOSITE LRNG DIFF
*	T65A00	1.12273	1.54091	T65A00	651	5.7402	0.2114	5.1891
				T65A00	688	5.5322	0.3622	
				T65A00	689	5.4297	0.1738	
				T65A00	690	5.3588	0.1975	
				T65A00	691	5.4302	0.2129	
				T65A00	692	5.2841	0.398	
				T65A00	693	5.5276	0.1271	
				T65A00	694	5.0954	0.4589	
				T65A00	695	5.0584	0.441	
				T65A00	696	4.9127	0.5584	
				T65A00	697	4.9254	0.7334	
	R65AA0	0.42273	0.47727					
*	V65A00	0.62273	0.80455	V65AAF	644	2.4875	1.2401	3.5953
				V65AC0	713	4.7198	0.1409	
				V65A00	716	4.8646	0.2303	
				V65A00	723	3.9026	0.34182	
				V65A00	725	4.7546	0.1944	
				V65A00	726	4.5106	0.6474	
*	T76C00	0.98889	1.17222	T76C00	751	5.4867	0.3571	5.4867
	R76CD0	0.57778	0.71667					
	R76CE0	0.85833	0.95					
	V76C00	0.295	0.38					
*	T76E00	1.53333	1.9625	T76E00	764	5.7311	0.7719	5.9624
				T76EC0	765	6.0961	0.4966	
				T76E00	766	6.0874	0.5586	
				T76E00	767	6.4003	0.204	
				T76EC0	768	5.7884	0.5241	
				T76E00	769	5.8724	0.6176	
				T76E00	771	5.5319	0.5768	
				T76E00	772	6.71	0.4654	
	R76ED0	0.85417	0.625					
	R76EE0	0.55	0.6125					
	R76EG0	0.44167	0.50417					
	R76EK0	0.56667	0.7					
*	V76E00	0.80417	1.02083	V76E00	199	5.4126	0.2125	4.5843
				V76E00	197	5.4556	0.9886	
				V76EA0	224	1.8605	0.3932	
				V76E00	778	4.9496	0.321	
				V76ED0	779	3.9828	0.4404	
				V76E00	780	4.3643	0.6166	
				V76E00	785	4.9671	0.8878	
				V76ED0	789	4.3065	0.0833	

* DATA POINTS USED IN REGRESSIONS OF SECONDARY TIME AGAINST WEIGHTED TASK LEARNING

APPENDIX F. ESTIMATING TRAINING REQUIREMENTS

F.1. Introduction

F-15 SMEs were asked to evaluate the training requirements for 5-level ATF avionics maintainers being cross trained to maintain F-15 UHF and IFF equipment. The SMEs were given detailed outlines of the contents of the three F-15 courses, the Initial Skills Course (Lowry AFB), the FTD course (Eglin AFB), and OJT. They were asked to identify any training the ATF maintainers would require and the total hours or a percentage of the F-15 training hours that would be needed for the cross training. The results of these surveys are shown in Sections F.2. (Initial Skills Course), F.3. (FTD Course), and F.4.(OJT)

Additionally , a top-down approach was used to confirm the OJT requirement. Section F.5 shows the questionnaires which asked the SMEs for the percentages of their total time in OJT allocated to UHF and IFF systems and subsystems. The results of this approach are also displayed in Section F.5.

Note that the data collected through these surveys are sparse and so cannot be used to reach firm conclusions regarding cross training requirements. However, the process followed to collect these data was a viable one which if followed with a larger SME sample, would generate more precise data.

F.2. Program of Instruction, Initial Skills Course for AFS 452X1C

POI G3AQR45231C-000, F-15 AVIONIC COMMUNICATION, NAVIGATION, AND PENETRATION AIDS SYSTEMS SPECIALTY (Dated 30 June 1989, LOWRY TECHNICAL TRAINING CENTER), is presented below with the following additions. POI objectives are displayed with projected course hours (classroom hours/self-study hours) in the column POI HRS. Hours for maintainers from another aircraft cross training to maintain F-15 UHF, IFF, and related systems, as estimated by four SMEs, are displayed in columns #1 HRS, #2 HRS, #3 HRS, and #4 HRS. The mean and standard deviation of the survey responses are displayed in the last two columns.

Hours associated with an individual line item of the POI are listed in parentheses. These hours are totaled and displayed adjacent to POI subheadings. The hours associated with the subheadings are totaled and displayed in bold print adjacent to the POI major headings.

SUMMARY: SME ESTIMATES FOR INITIAL SKILLS COURSE, AFS 452X1C

COURSE ITEM	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
I. ELECTRONIC PRINCIPLES							
II. INTRODUCTION TO MAINTENANCE	24.5/8	0/0	0/0	0/0	0/0		
III. GENERAL MAINTENANCE PROCEDURES	34.5/ 12	0/0	4.275/ 1.95	4.6/4.5	6.925/ 2.0	3.95/ 2.11	2.50/ 1.60
IV. COMM/NAV AND PENETRATION AIDS SYSTEM I	58.5/ 20	11.125/ 4.5	47.25/ 17	34/ 12.75	26.25/ 7.5	29.75/ 10.44	13.20/ 4.80
V. COMM/NAV AND PENETRATION AIDS SYSTEM II	34.5/ 12	6.75/ 2.75	17.25/ 6.75	15.0/ 5.75	20.5/ 6.5	14.88/ 5.44	5.08/ 1.59
VI. TACTICAL ELECTRONIC WARFARE SYSTEM	22.5/8	0/0	0	0	0		
VII. PENETRATION AIDS SYSTEM	26/8	0/0	0	0	4/1	1.0	1.73
TOTAL HOURS	200.5/ 68	17.88/ 7.25	69.15/ 25.7	53.6/ 23.0	57.7/ 17	49.6/ 18.2	19.2/ 7.1

DETAIL: SME ESTIMATES FOR INITIAL SKILLS COURSE, AFS 452X1C

COURSE ITEM	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
I. ELECTRONIC PRINCIPLES							
II. INTRODUCTION TO MAINTENANCE	**24.5/8**	**0/0**	**0/0**	**0/0**	**0/0**		
II.1. Orientation	1/0	0/0	0/0	0/0	0/0		
II.2. Career Ladder Structure	2.5/0	0/0	0/0	0/0	0/0		
II.2.a. Given an Air Force Specialty Code with a suffix, identify the elements of the AFSC.	(.5/0)						
II.2.b. Given a list of statements, identify the duties of the 3, 5, and 7 skill levels.	(2/0)						
II.3. Specific Vulnerabilities of AFSC	1.5/0	0/0	0/0	0/0	0/0		
II.3.a. Given scenarios with Operations Security vulnerabilities, identify the specific vulnerabilities of the 452xx career field described in each scenario.							
II.4. Physical Security	2.5/1	0/0	0/0	0/0	0/0		
II.4.a. Given a list of statements, select the statements that pertain to physical security.							
II.5. AF Occupational Safety and Health (AFOSH)	8/3	0/0	0/0	0/0	0/0		
II.5.a. Given a list of AF Occupational Safety and Health (AFOSH) Program standards, identify the AFOSH standards for the 452xx career field.	(.5/1)						
II.5.b. Given a list of hazards, identify the hazards of Radio Frequency (RF) energy.	(.5/0)						
II.5.c. Given extracts from AFOSH standard 161-9, identify the steps in reporting suspected RF overexposure.	(1/0)						
II.5.d. Given a list of safety practices, identify the safety practices used with RF sources.	(.5/0)						

COURSE ITEM	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
II.5.e. Given a list of safety practices, identify the safety practices used with compressed gases.	(.5/0)						
II.5.f. Given a list of safety practices, identify the safety practices used with electrical power.	(.5/0)						
II.5.g. Given a list of safety practices, identify the safety practices used with hydraulic power.	(.5/0)						
II.5.h. Given a list of safety practices, identify the safety practices used with hazardous liquids	(.5/0)						
II.5.i. Given a list of safety practices, identify the safety practices used with portable fire extinguishers.	(.5/0)						
II.5.j. Given a list of safety practices, identify the safety practices used with high intensity sound.	(.5/.5)						
II.5.k. Given a list of statements, identify the statements that describe the procedures in keeping the work area clean and safe.	(.5/.5)						
II.5.l. Given a list of statements, identify the statements that describe the procedures in preventing Foreign Object Damage (FOD).	(1/.5)						
II.5.m. Given a list of statements, identify the statements that describe hydrazine hazards.	(1/.5)						
II.6. Supply Discipline	2.5/0	0/0	0/0	0/0	0/0		
II.6.a. Given a list of statements, identify the statements as pertaining to either property accountability or property responsibility.	(1/0)						
II.6.b. Given examples yellow, green, and red conditions tags, and scenarios involving equipment status, complete the proper tag for each scenario.	(1.5/0)						
II.7. Maintenance Management	6.5/4	0/0	0/0	0/0	0/0		

COURSE ITEM	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
II.7.a. Given a list of functions and responsibilities, identify the functions and responsibilities of the Deputy Commander (DCM) for maintenance and the DCM staff agencies.	(2.25/ 1)						
II.7.b. Given a list of statements, identify the statements that describe Maintenance Data Collection (MDC).	(2.25/ 1)						
II.7.c. Given a list of statements, identify the statements that pertain to processing and controlling material.	(2/2)						
III. GENERAL MAINTENANCE PROCEDURES	**34.5/ 12**	**0/0**	**4.275/ 1.95**	**4.6/4.5**	**6.925/ 2.0**	**3.95/ 2.11**	**2.50/ 1.60**
III.1. Technical Publications	10.5/2	0/0	1.125/ .5	3.6/4	2.625/ 1.0	1.84/ 1.38	1.38/ 1.56
III.1.a. Given a list of statements, select the statements that describe the function or application of technical publications.	(3/0)						
III.1.b. Given applicable TOs and statements which require locating technical information to complete a task, identify where the information is located.	(4.5/2)		(1.125/ .5)	(3.6/4)			
III.1.c. Given two technical order (TO) numbers and TO indexes 0-1-01,0-1-02, and 0-1-4; locate the title, basic date, latest change date, and supplement for the TOs.	(1.5/0)						
III.1.d. Given a list of statements, identify the statements that describe Computer Program Identification Numbers (CPIN).	(1.5/0)						
III.2. Maintenance, Inspection Systems and Forms	12/4	0/0	1.05/.2	0/0	0/0	.26/.05	.45/.0 9
III.2.a. Given a list of statements, identify the level of maintenance described in each statement.	(1/0)		(.25/0)				
III.2.b. Given a list of statements, identify the type of inspection system described in each statement.	(2/0)		(.5/0)				

COURSE ITEM	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
III.2.c. Given a scenario describing a maintenance action, complete an example of an AFTO Form 781A.	(3/2)		(.3/.2)				
III.2.d. Given applicable TOs and a scenario, complete examples of AFTO Forms 349 and 350.	(3/2)						
III.2.e. Given a list of statements, identify the statements that pertain to Core Automated Maintenance System (CAMS).	(1/0)						
III.2.f. Given a list of statements, identify the statements that pertain to the deficiency reporting system.	(2/0)						
III.3. Corrosion Control	1/0	0/0	0/0	0/0			
III.3.a. Given a list of statements, identify the statements that pertain to corrosion control.							
III.4. Protection, Safety Wiring, Torque Indicating Devices, and CTK Procedures	5/2	0/0	1.4/.7	1/.5	2.5/1.0	1.23/.5 5	.90/.3 6
III.4.a. Given a list of devices, identify the device(s) used to protect exposed electrical connectors, open pressure lines, and open waveguides.	(1/.5)		(1.1/ .55)	(1/.5)			
III.4.b. Given statements, select the statements that pertain to steps involved in safety wiring.	(1/.5)		(.05/ .025)				
III.4.c. Given statements, select the statements that pertain to steps involved in using torque indicating devices.	(1/.5)		(.25/ .125)				
III.4.d. Given statements, select the statements that pertain to steps involved in following CTK procedures.	(2/5)						
III.5. Chafing	3/2	0/0	.25/.25	0/0	.9/0	.29/.06	.37/.1 1
III.5.a. Given a list of statements, identify the statements that define chafing.	(1/1)		(.25/ .25)				

COURSE ITEM	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
III.5.b. Given a list of statements, identify the statements that describe the causes of chafing.	(2/1)						
III.6. Cable Inspection	3/2	0/0	.45/.30	0/0	.9/0	.34/.08	.37/.13
III.6.a. Given a list of statements, identify the statements that describe the signs of deterioration in RF cables.			(.45/ .30)				
IV. COMM/NAV AND PENETRATION AIDS SYSTEM I	**58.5/ 20**	**11.125/ 4.5**	**47.25/ 17**	**34/ 12.75**	**26.25/ 7.5**	**29.75/ 10.44**	**13.20/ 4.80**
IV.1. Aircraft Familiarization	8/2	0/0	6.5/1.5	6.5/1.5	0/0	3.25/.75	3.25/ .75
IV.1.a. Given applicable TO and a list of major components, identify the major structural area where each component is located.	(3/0)		(3/0)	(3/0)			
IV.1.b. Given applicable TO and a list of major components, identify the major aircraft system described in each statement.	(2/1)		(2/1)	(2/1)			
IV.1.c. Given applicable TO and a list of major components, identify the danger area described in each statement.	(3/1)		(1.5/.5)	(1.5/ .5)			
IV.2. Aircraft Avionics Familiarization	3/1	0/0	1/1	3/1	0/0	1/.5	1.22/ .5
IV.2.a. Given a list of systems, identify the systems which make up the A shred.	(1/0)			(1/0)			
IV.2.b. Given a list of systems, identify the systems which make up the B shred.	(1/0)			(1/0)			
IV.2.c. Given a list of systems, identify the systems which make up the C shred.	(1/1)		(1/1)	(1/1)			
IV.3. UHF Communication and Audio Signal System	28/9	9.5 /3.5	24.5/ 7.75	24.5/ 10.25	14/4.5	18.1/6.5	6.57/ 2.68

COURSE ITEM	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
IV.3.a. Given applicable TO and a list of statements, identify the UHF or audio signal system Line Replaceable Unit (LRU) described in each statement.	(6/3)	(3/1.5)	(4.5/ 2.25)	(4.5/ 2.25)			
IV.3.b. Given applicable TO and a list of statements, identify the statements that pertain to UHF or audio signal theory of operation.	(8/2)	(0/0)	(6/1.5)	(6/2)			
IV.3.c. Given a list of conditions existing in the UHF or audio signal system and applicable TOs, trace the signal/data flow within the UHF or audio signal system.	(8/2)	(2/.5)	(8/2)	(8/2)			
IV.3.d. Given scenarios involving UHF or audio signal system malfunctions and applicable TOs, isolate the cause of the malfunctions in each scenario.	(6/2)	(4.5/ 1.5)	(6/2)	(6/4)			
IV.4. Automatic Direction Finder (ADF) System	7/2	0/0	6.125/ 1.75	0/0	3.5/0	2.41/.4 4	2.58/ .76
IV.4.a. Given applicable TO and a list of statements, identify the statements that pertain to Automatic Direction Finder (ADF) system theory of operation.	(3.5/1)		(2.625/ .75)				
IV.4.b. Given a list of conditions existing in the ADF system and applicable TOs, trace the signal/data flow within the ADF system.	(3.5/1)		(3.5/1)				
IV.5. Crypto Equipment, Secure Voice	12.5/6	1.625/1	9.5/5	0/0	8.75/ 3.0	4.97/ 2.25	4.20/ 1.92
IV.5.a. Given applicable TO and a list of statements, identify the statements that pertain to secure voice theory of operation.	(6/2)	(0/0)	(3/1)				
IV.5.b. Given a list of conditions existing in the secure voice system and applicable TOs, trace signal/data flow within the secure voice system.	(6.5/4)	(1.625/ 1)	(6.5/4)				
V. COMM/NAV AND PENETRATION AIDS SYSTEM II	**34.5/ 12**	**6.75/ 2.75**	**17.25/ 6.75**	**15.0/ 5.75**	**20.5/ 6.5**	**14.88/ 5.44**	**5.08/ 1.59**

COURSE ITEM	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
V.1. Instrument Landing System (ILS)	6/1	0/0	0/0	0/0	0/0		
V.1.a. Given applicable TO and a list of statements, identify the statements that pertain to the Instrument Landing System (ILS) theory of operation.	(4/0)						
V.1.b. Given a list of conditions existing in the ILS and applicable TOs, trace signal/data flow within the ILS.	(2/1)						
V.2. Tactical Air Navigation (TACAN) System	8/3	0/0	0/0	0/0	0/0		
V.2.a. Given applicable TO and a list of statements, identify the statements that pertain to Tactical Air Navigation (TACAN) System theory of operation.	(4/1)						
V.2.b. Given a list of conditions existing in the TACAN system and applicable TOs, trace signal/data flow within the TACAN system.	(2/1)						
V.2.c. Given scenarios involving TACAN system malfunctions and applicable TOs, isolate the cause of the malfunction in each scenario.	(2/1)						
V.3. Identification Friend or Foe (IFF) System	6/2	.625/ .25	5.125/ 1.75	6/2.5	6/2	4.44/ 1.63	2.23/ .84
V.3.a. Given applicable TO and a list of statements, identify the statements that pertain to Identification Friend or Foe (IFF) System theory of operation.	(3.5/1)	(0/0)	(2.625/ .75)	(3.5/1)			
V.3.b. Given a list of conditions existing in the IFF system and applicable TOs, trace signal/data flow within the IFF system.	(2.5/1)	(.625/ .25)	(2.5/1)	(2.5/ 1.5)			
V.4. Air-to-air IFF Interrogator (AAI) System	9/3	3.75/1	7.5/ 2.75	9/3.25	9/3	7.31/ 2.50	2.15/ .88
V.4.a. Given applicable TO and a list of statements, identify the Air-to-Air IFF Interrogator (AAI) System LRU described in each statement.	(2/0)	(1/0)	(1/0)	(2/0)			

COURSE ITEM	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
V.4.b. Given applicable TO and a list of statements, identify the statements that pertain to AAI system theory of operation.	(2/1)	(0/0)	(1.5/ .75)	(2/1)			
V.4.c. Given a list of conditions existing in the AAI system and applicable TOs, trace signal/data flow within the AAI system.	(2/1)	(.5/.25)	(2/1)	(2/1)			
V.4.d. Given scenarios involving AAI system malfunctions and applicable TOs, trace signal/data flow within the AAI system.	(3/1)	(2.25/ .75)	(3/1)	(3/ 1.25)			
V.5. Crypto Equipment, Mode 4	5.5/3	2.375/ 1.5	4.625/ 2.25	0/0	5.5/1.5	3.125/ 1.313	2.134/ .817
V.5.a. Given applicable TO and a list of statements, identify the Mode 4 system LRU described in each statement.	(1/1)	(.5/.5)	(.5/.5)				
V.5.b. Given applicable TO and a list of statements, identify the statements that pertain to Mode 4 system theory of operation.	(1/0)	(0/0)	(1/0)				
V.5.c. Given a list of conditions existing in the Mode 4 system and applicable TOs, trace signal/data flow within the Mode 4 system.	(1.5/1)	(.375/ .25)	(1.125/ .75)				
V.5.d. Given scenarios involving Mode 4 system malfunctions and applicable TOs, isolate the cause of the malfunction in each scenario.	(2/1)	(1.5/ .75)	(2/1)				
VI. TACTICAL ELECTRONIC WARFARE SYSTEM	**22.5/8**	**0/0**	**0**	**0**	**0**		
VI.1. Radar Warning Receiver (RWR)	13/4	0/0	0/0	0/0	0/0		
VI.1.a. Given applicable TO and a list of statements, identify the statements that pertain to Radar Warning Receiver (RWR) system theory of operation.	(6/2)						
VI.1.b. Given a list of conditions existing in the RWR and applicable TOs, trace signal/data flow within the RWR.	(3/0)						

COURSE ITEM	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
VI.1.c. Given scenarios involving RWR system malfunctions and applicable TOs, isolate the cause of the malfunction in each scenario.	(4/2)						
VI.2. Internal Countermeasure System (ICMS)	9.5/4	0/0	0/0	0/0	0/0		
VI.2.a. Given applicable TO and a list of statements, identify the statements that pertain to Internal Countermeasure System (ICMS) system theory of operation.	(4.5/1)						
VI.2.b. Given a list of conditions existing in the ICMS and applicable TOs, trace signal/data flow within the ICMS.	(5/3)						
VII. PENETRATION AIDS SYSTEM	**26/8**	**0/0**	**0**	**0**	**4/1**	**1.0**	**1.73**
VII.1. Course Critique	1/0	0/0	0/0	0/0	0/0		
VII.2. External Countermeasures System (PODS)	6/2	0/0	0/0	0/0	0/0		
VII.2.a. Given applicable TO and a list of statements, identify the statements that pertain to the External Countermeasures System (PODS) theory of operation.	(4/1)						
VII.2.b. Given a list of conditions existing in the PODS and applicable TOs, trace signal/data flow within the PODS.	(2/1)						
VII.3. Interference Blanker System (IBS)	8/2	0/0	0/0	0/0	4/1	1.0/.25	1.73/ .43
VII.3.a. Given applicable TO and a list of statements, identify the statements that pertain to the Interference Blanker System (IBS) theory of operation	(5/1)						
VII.3.b. Given a list of conditions existing in the IBS and applicable TOs, trace signal/data flow within the IBS.	(3/1)						
VII.4. Countermeasure Dispenser System	11/4	0/0	0/0	0/0	0/0		

COURSE ITEM	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
VII.4.a. Given applicable TO and a list of statements, identify the statements that pertain to the Countermeasure Dispenser System (CDS) theory of operation.							
TOTAL HOURS	**200.5/ 68**	**17.88/ 7.25**	**69.15/ 25.7**	**53.6/ 23.0**	**57.7/ 17**	**49.6/ 18.2**	**19.2/ 7.1**

F.3. Program of Instruction, FTD Course for AFS 452X1C

POI J4ABF45231C-002, F-15 AVIONIC SYSTEMS SPECIALTY (COMM, NAV AND PEN AIDS),(SHEPPARD TECHNICAL TRAINING CENTER, Dated 1 June 1989) is presented below with the following additions. POI HRS contains the training hours scheduled for each objective. Columns #1 HRS, #2 HRS, #3 HRS, and #4 HRS contain estimates by 4 SMEs of the cross training required for maintainers from another aircraft to learn to maintain F-15 UHF, IFF, and related systems. The means and standard deviations of these estimates are contained in the final two columns.

Hours associated with individual line items of the POI are listed in parentheses. These hours are totaled and displayed adjacent to POI subheadings. The hours associated with the subheadings are totaled and displayed in bold print adjacent to the POI major headings.

SUMMARY: SME ESTIMATES FOR FTD COURSE, AFS 452X1C

COURSE OBJECTIVE		POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
I.	AIRCRAFT GENERAL	21	12	0	5	0	4.25	4.92
II.	COMMUNICATION AND NAVIGATION SYSTEMS	50	37	8.2+	17.15	22.4	21.18	10.45
III.	TACTICAL ELECTRONIC WARFARE SYSTEMS (TEWS)	31	0	0	0	1	.25	.43
IV.	WIRING REPAIR	10	0	0	0	10	2.5	4.3
	TOTAL HOURS	112	49	8.2+	22.15	33.4	28.2	**15.0**

DETAIL: SME ESTIMATES FOR FTD COURSE, AFS 452X1C

COURSE OBJECTIVE	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
I. AIRCRAFT GENERAL	**21**	**12**	**0**	**5**	**0**	**4.25**	**4.92**
I.1. Course Orientation	1	0	0	0	0	--	--
I.2. Aircraft General	20	12	0	5	0	4.25	4.92
I.2.a. Given TOs and an aircraft, perform an aircraft safe for maintenanceinspection with no instructor assistance.	(6)	(6)	(0)	(1.5)	(0)	(1.88)	(2.46)
I.2.b. Given TOs, an aircraft, external power unit, a ground air conditioning unit, and working as a team member, perform external power and cooling air application and removal procedures with no more than three instructor assists per team.	(6)	(6)	(0)	(1.5)	(0)	(1.88)	(2.46)
I.2.c. Given TOs, an aircraft, external power unit, hydraulic power unit, and working as a team member, perform external utility hydraulic power application and removal procedures with no more than four instructor assists per team.	(8)	(0)	(0)	(2)	(0)	(.5)	(.866)
II. COMMUNICATION AND NAVIGATION SYSTEMS	**50**	**37**	**8.2+[34]**	**17.15**	**22.4**	**21.18**	**10.45**
II.1. Organizational Maintenance Systems of the F-15 Communication System	12	12	4	2.15	5.5	5.91	3.71
II.1.a. Given TOs, F-15 Aircraft/Flight simulator/TFE-15, and AGE, perform an Aux Receiver and ICCP BIT Checkout with no more than two instructor assists.	(3)	(3)	(.9)	(.9)	(1.5)	(1.585)	(.858)
II.1.b. Given TOs, F-15 Aircraft/TFE-15, AGE, and working as a team member, perform a UHF Communication and Audio Signal System Operational checkout with no more than five instructor assists per team.	(5)	(5)	(1.5)	(1.25)	(2.0)	(2.170)	(1.308)

[34] The plus sign (+) indicates that the SME believed a training requirement existed but that the SME felt unqualified to make an estimate.

COURSE OBJECTIVE	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
II.1.c. Given TOs, F-15 Aircraft/Flight simulator/TFE-15, and AGE, perform an ADF BIT checkout with no more than two instructor assists.	(2)	(2)	(.6)	(0)	(1.0)	(.9)	
II.1.d. Given TOs, F-15 Aircraft/TFE-15, and AGE, perform an ADF operational checkout with no more than two instructor assists.	(2)	(2)	(1)	(0)	(1.0)	(1.0)	(.707)
II.2. Organizational Maintenance of the F-15 Navigation System	38	25	4.20+	15	16.9	15.3	7.4
II.2.a. Given TOs, F-15 Aircraft/TFE, AGE, Test Equipment, and working as a team member, perform an ILS Operational Checkout with no more than three instructor assists per team.	(3)	(0)	(0)	(0)	(0)		
II.2.b. Given TOs, F-15 Aircraft/Flight Simulator/TFE-15, and AGE, perform a TACAN BIT checkout with no more than two instructor assists.	(3)	(0)	(0)	(0)	(0)		
II.2.c. Given TOs, F-15 Aircraft/TFE-15, and AGE, perform a TACAN operational checkout with no more than three instructor assists.	(3)	(0)	(0)	(0)	(0)		
II.2.d. Given TOs, F-15 Aircraft, AGE, test equipment, and working as a team member, perform fault isolation procedures of Tactical Air Navigation System with no more than five instructor assists per team.	(4)	(0)	(0)	(0)	(0)		
II.2.e. Given TOs, AFTO Forms 349 and 350, and simulated maintenance data, document on-equipment maintenance with no more than three errors per AFTO Form.	(3)	(3)	(0)	(0)	(0)		
II.2.f. Given TOs, F-15 Aircraft/Flight Simulator/TFE-15, and AGE, perform an IFF Transponder BIT Checkout with no more than two instructor assists.	(3)	(3)	(.9)	(3)	(.9)	(1.95)	(1.05)

COURSE OBJECTIVE	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
II.2.g. Given TOs, F-15 Aircraft, AGE, test equipment and working as a team member, perform an IFF operational checkout using AN/APM-424 with no more than three instructor assists per team.	(3)	(3)	(1.5)	(3)	(3)	(2.625)	(.6495)
II.2.h. Given TOs, F-15 Aircraft/TFE-15, and AGE, perform an Air-to-Air and Mode 4 IFF BIT checkout with no more than two instructor assists.	(6)	(6)	(1.8)	(3)	(3)	(3.45)	(1.552)
II.2.i. Given TOs, F-15 Aircraft/TFE-15, AGE test equipment, and working as a team member, perform an Air-to-Air IFF operational checkout using AN/APM-349 with no more than four instructor assists per team.	(6)	(6)	+	(3)	(6)	(5)	(1.41)
II.2.j. Given TOs, F-15 Aircraft, AGE, test equipment, and working as a team member, perform fault isolation procedures of the Air-to-Air IFF system with no more than five instructor assists per team.	(4)	(4)	(0)	(3)	(4)	(2.75)	(1.64)
III. TACTICAL ELECTRONIC WARFARE SYSTEMS (TEWS)	**31**	**0**	**0**	**0**	**1**	**.25**	**.43**
III.1. Organizational Maintenance of the Tactical Electronic Warfare Systems (TEWS)	31	0	0	0	1	.25	.43
III.1.a. Given TOs, F-15 Aircraft/Flight Simulator/TFE-15, and AGE, perform a RWR BIT with no more than two instructor assists.	(3)	(0)	(0)	(0)	(0)	(0)	(0)
III.1.b. Given TOs, F-15 Aircraft TFE-15 AN/APM-427 Test Set, AGE, and working as a team member, perform an Improved Radar Simulator Checkout with no more than three instructor assists per team.	(3)	(0)	(0)	(0)	(0)	(0)	(0)
(0)III.1.c. Given TOs, identify relationship of basic facts and principles about Electronic Warfare Warning System (EWWS) with a minimum of 70 percent accuracy.	(6)	(0)	(0)	(0)	(0)	(0)	(0)

COURSE OBJECTIVE	POI HRS	#1 HRS	#2 HRS	#3 HRS	#4 HRS	MEAN HRS	STD DEV
III.1.d. Given TOs, identify malfunctions for the EWWS with a minimum of 70 percent accuracy.	(6)	(0)	(0)	(0)	(0)	(0)	(0)
III.1.e. Given TOs, F-15 Aircraft/Flight Simulator/TFE-15, and AGE, perform an EWWS BIT with no more than three instructor assists.	(3)	(0)	(0)	(0)	(0)	(0)	(0)
III.1.f. Given TOs, F-15 Aircraft, AN/ALM-231 Test Set, AGE, and working as a team member, perform a Walk-Around Transportable Test Set procedure with no more than three instructor assists per team.	(3)	(0)	(0)	(0)	(0)	(0)	(0)
III.1.g. Given TOs, F-15 Aircraft/Flight Simulator/TFE-15, AGE, and test equipment, perform an ICMS BIT Checkout with no more than two instructor assists.	(2)	(0)	(0)	(0)	(0)	(0)	(0)
III.1.h. Given TOs, F-15 Aircraft, AGE, and test equipment, perform an ICMS pressurization checkout with no more than two instructor assists.	(3)	(0)	(0)	(0)	(0)	(0)	(0)
III.1.i. Given TOs, F-15 Aircraft/Flight Simulator/TFE-15, and AGE, perform an IBS BIT with no more than two instructor assists.	(2)	(0)	(0)	(0)	(1)	(.25)	(.433)
IV. WIRING REPAIR	**10**	**0**	**0**	**0**	**10**	**2.5**	**4.3**
IV.1. Wiring Repair	10	0	0	0	10	2.5	4.3
IV.1.a. Given TOs, aircraft ID number, aircraft model, reference designator number, and pin number, locate information and tools to repair a defective wire with no more than four errors.	(5)	(0)	(0)	(0)	(5)	(1.25)	(2.17)
IV.1.b. Given TO, TDR, and a sample test cable.	(2)	(0)	(0)	(0)	(2)	(.5)	(.87)
IV.1.c. Given applicable TOs, a solderless connector repair kit, and a multi-pin connector with wire and pins: remove, reterminate, reinsert a pin with no more than two instructor assists.	(3)	(0)	(0)	(0)	(3)	(.75)	(1.30)
TOTAL HOURS	**112**	**49**	**8.2+**	**22.15**	**33.4**	**28.2**	**15.0**

F.4. Specialty Training Standard (STS) 452X1 (Dated February 1991.)

The following table is derived from STS 452X1, the standard which describes the "common tasks, knowledge, and technical references (TR) necessary for airmen to perform duties at the 3-, 5- and 7-skill level AFSC in the Integrated Organizational Avionics F-15 Systems ladder of the Airman Avionics System Career Field." The complete STS was presented to three SMEs who reviewed it to identify the line items necessary for the cross training of an ATF avionics maintainer to F-15 UHF and IFF. While the SMEs reviewed the entire document, only those portions identified by at least one SME as necessary for cross training are displayed below. #3 TIME contains the joint response of SME respondents 2 and 3, and #4 TIME contains the response of the last SME; the final column contains the mean of these estimates.

TASK TITLE		#3 TIME (HRS)	#4 TIME (HRS)	MEAN TIME
15.	USE TEST EQUIPMENT	5.5		2.75
15a.	Boresight			
15b.	RF tester			
15c.	WOW/proximity box			
15d.	Waveguide pressure tester			
15a.	Memory/loader verifier			
15f.	Transmission tester			
15g.	Fuel quantity tester			
15h.	Hydrometer			
15i.	Compass calibrator			
15j.	Standby compass calibrator			
15k.	TTU-205 C/E			
15l.	Automatic Flight Control test set			
15m.	Linear gauge (Pogo Stick)			
15n.	Thru-line WATT meter			
15o.	ILS test set			
15p.	IFF test set	1		.5
15q.	AAI test set	4.5		2.25
15r.	Radar target simulator			
15s.	HPRF target generator			
15t.	Time domain reflectometer			
15u.	Antenna diode tester			

TASK TITLE		#3 TIME (HRS)	#4 TIME (HRS)	MEAN TIME
45.	UHF COMMUNICATION AND AUDIO SIGNAL SYSTEM	23	33	28
45a.	Theory of operation		5	2.5
45b.	Trace wiring, system, and interface diagrams		5	2.5
45c.	Perform operational checkout and BIT	2	2	2
45d.	Isolate malfunctions	14	10	12
45e.	Remove system LRU(s)	.5	4	2.25
45f.	Install system LRU(s)	.5	4	2.25
45g.	Code/Decode KY unit	6	3	3.75
46.	AUTOMATIC DIRECTION FINDER (ADF) SYSTEM		17	8.5
46a.	Theory of Operation		3	1.5
46b.	Trace wiring, system, and interface diagrams		3	1.5
46c.	Perform operational checkout and BIT		2	1
46d.	Isolate malfunctions		5	2.5
46e.	Remove system LRU(s)		2	1
46f.	Install system LRU(s)		2	1
49.	IDENTIFICATION FRIEND OR FOE (IFF) SYSTEM AND MODE 4 SYSTEM	16.5	32	24.25
49a.	Theory of operation		5	2.5
49b.	Trace wiring, system, and interface diagrams		5	2.5
49c.	Perform operational checkout and BIT	1	2	1.5
49d.	Isolate malfunctions	14	10	12
49e.	Remove system LRU(s)	.5	4	2.25
49f.	Install system LRU(s)	.5	4	2.25
49g.	Code/decode Mode 4	.5	2	1.25
50.	AIR-TO-AIR IFF INTERROGATOR (AAI) SYSTEM AND MODE 4 SYSTEM	33.5	45	39.25
50a.	Theory of operation		10	5
50b.	Trace wiring, system, and interface diagrams		10	5
50c.	Perform operational checkout and BIT	2	5	3.5
50d.	Isolate malfunctions	30	10	20
50e.	Remove system LRU(s)	.5	4	2.25
50f.	Install system LRU(s)	.5	4	2.25
50g.	Code/decode Mode 4	.5	2	1.25

TASK TITLE		#3 TIME (HRS)	#4 TIME (HRS)	MEAN TIME
53.	INTERFERENCE BLANKER SYSTEM (IBS)		9	4.5
53a.	Theory of operation		2	1
53b.	Trace wiring, system, and interface diagrams		2	1
53c.	Perform BIT		1	.5
53d.	Isolate malfunctions		2	1
53e.	Remove system LRU(s)		1	.5
53f.	Install system LRU(s)		1	.5
	TOTAL HOURS	78.5	136	107.25
	UHF HOURS[35]	23.0	54.5	38.75
	IFF HOURS[36]	55.5	81.5	68.5

[35] UHF hours collected from topics 45, 46, and 53(50%).

[36] IFF hours collected from topics 15, 49, 50, and 53(50%).

F.5. OJT Questionnaires

Questionnaires were presented to new 5-skill level airmen and OJT instructors to obtain their estimates of the OJT training requirement for avionics maintenance personnel on the UHF and IFF systems of the F-15. The survey responses are displayed and tabulated below; the questionnaires themselves follow.

Each pair of columns corresponds to the respondent with the same number in the preceding survey response tables. Columns 2A, 3A, and 4A are the responses as they were supplied by the respondents; columns 2B, 3B, and 4B are those responses converted to OJT time based on 48 work weeks per year, 5 work days per week, and 8 work hours per day. Column 3A contains data from the only survey respondent who is currently an OJT instructor. Based upon the instructor's statement that the 3 to 5 skill level OJT period typically lasts twelve months, the other survey responses were standardized to twelve month training periods as well.

Using the survey responses as standardized to twelve month OJT periods, UHF training requires 57.0 hours (std=.9 hrs) and IFF training requires 145.9 hours (std=25.9hrs).

SURVEY QUESTION	#2A	#2B	#3A	#3B	#4A	#4B
1. A. Initial skills course	9/17/90-1/29/91	5 months	-	-	6 months	6 months
B. FTD	2/1/91-3/1/91	1	-	-	3	3
C. OJT	3/1/91-3/31/92	13	12 months	12 months	5/89-7/91[35]	27
2. % OJT	30%	624 hrs	30%	576 hrs	30%	1296 hrs
3. % UHF	10%	62.4 hrs	10%	57.6 hrs	10%	129.6 hrs
4. 63A	8.0%	49.9 hrs	80%	46.1 hrs	40%	51.8 hrs
63B	1.0%	6.2	10%	5.8	10%	13.0
63C	.2%	1.2	5%	2.9	10%	13.0
63D	.5%	3.1	5%	2.9	10%	13.0
Total UHF		60.4 hrs		57.7 hrs		129.6 hrs
5. %IFF	30%	187.4 hrs	25%	144.0 hrs	20%	259.2 hrs
6. 65A	15%	93.6 hrs	45%	64.8 hrs	45%	116.6 hrs
65B	15%	93.6	45%	64.8	45%	116.6
65C	1%	6.2	10%	14.4	10%	25.9
Total IFF		193.4 hrs		144.0 hrs		259 hrs
Standardized to 12 months:						
UHF		55.8 hrs		57.7 hrs		57.6 hrs
IFF		178.5		144.0		115.1
TOTAL HOURS		234.3 hrs		201.7 hrs		172.7 hrs

[35] Includes time deployed to Operation Desert Shield/Storm.

OJT Questionaire for New 5-levels
Percent Time

1. Please list the training courses you attended, including dates, from completion of BMT until you were awarded your 5-level (45251C).

Example:

Initial skill course:	Oct 1990 - Feb 1991
FTD course:	Mar 1990 - Mar 1990
OJT (upgrade training) at Langley	Apr 1991 - Mar 1992

2. On average, what percentage each day did you spend in OJT?

3. What percentage of your OJT time was spent on the UHF communication system?

4. What percentage of your UHF OJT time was spent on each 3-digit WUC set comprising the UHF communication system (see below)?

UHF Communications

WUC	System	Subsystem
63A	UHF Communications	UHF Comm set
63B	UHF Communications	Integ CNI control set
63C	UHF Communications	Intercomm system
63D	UHF Communications	SEEK TALK

5. What percentage of your OJT time was spent on the IFF system?

6. What percentage of your IFF OJT time was spent on each 3-digit WUC set comprising the IFF system (see below)?

Identification Friend or Foe

WUC	System	Subsystem
65A	IFF	Transponder set
65B	IFF	IFF interrogator set
65C	IFF	IFF antenna set switch

Figure F.1: OJT Questionnaire for New 5-Levels

OJT Questionaire for OJT Instructors
Percent Time

1. On average, what percentage each day does a 3-level spend in OJT (upgrade training)?

2. On average, how many months does a 3-level spend in OJT before upgrade to the 5-level?

3. What is the average ratio of students to instructors during the time a 3-level spends in OJT?

3. On average, what percentage of a 3-level's OJT time is spent on the UHF communication system?

4. On average, what percentage of a 3-level's UHF OJT time is spent on each 3-digit WUC set comprising the UHF communication system (see below)?

UHF Communications

WUC	System	Subsystem
63A	UHF Communications	UHF Comm set
63B	UHF Communications	Integ CNI control set
63C	UHF Communications	Intercomm system
63D	UHF Communications	SEEK TALK

5. On average, what percentage of a 3-level's OJT time is spent on the IFF system?

6. On average, what percentage of a 3-level's IFF OJT time is spent on each 3-digit WUC set comprising the IFF communication system (see below)?

Identification Friend or Foe

WUC	System	Subsystem
65A	IFF	Transponder set
65B	IFF	IFF interrogator set
65C	IFF	IFF antenna set switch

Figure F.2: OJT Questionnaire for OJT Instructors